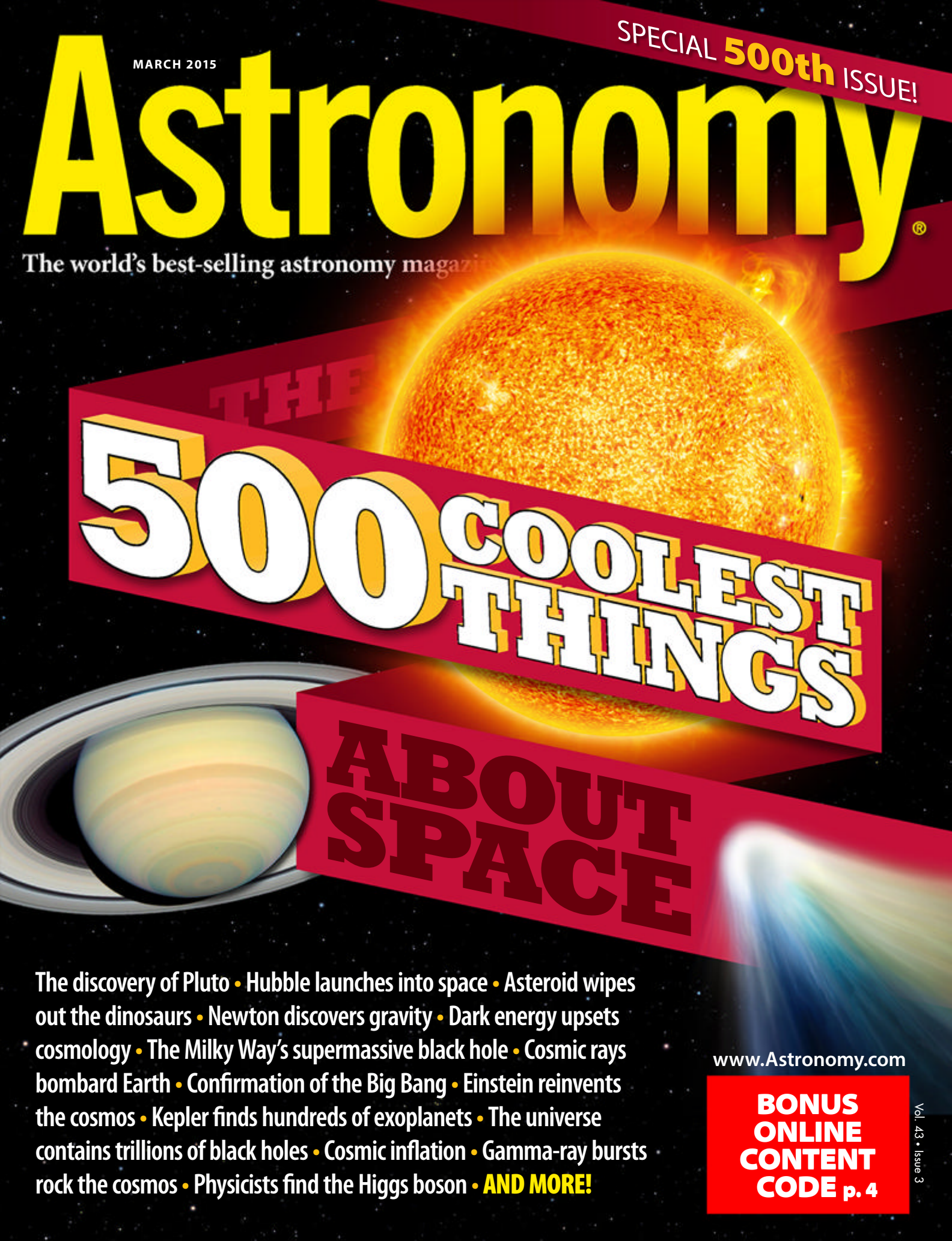
MARCH 2015

SPECIAL 500th ISSUE!

Astronomy®

The world's best-selling astronomy magazine



THE 500 COOLEST THINGS ABOUT SPACE

The discovery of Pluto • Hubble launches into space • Asteroid wipes out the dinosaurs • Newton discovers gravity • Dark energy upsets cosmology • The Milky Way's supermassive black hole • Cosmic rays bombard Earth • Confirmation of the Big Bang • Einstein reinvents the cosmos • Kepler finds hundreds of exoplanets • The universe contains trillions of black holes • Cosmic inflation • Gamma-ray bursts rock the cosmos • Physicists find the Higgs boson • **AND MORE!**

www.Astronomy.com

BONUS ONLINE CONTENT CODE p. 4

Vol. 43 • Issue 3

CELESTRON
UNIVERSALLY SUPERIOR

StarSense™ AUTOALIGN

YOUR TELESCOPE JUST GOT SMARTER.

Upgrade your telescope with the quickest, most accurate alignment technology available, StarSense AutoAlign. This groundbreaking accessory replaces your finderscope and hand control with a fully automated system that can align itself in under 3 minutes.

WITH STARSENSE, YOU'LL GET

Our easiest alignment

Just plug in the camera accessory and hand control and your Celestron computerized telescope aligns itself in minutes with no user input needed. Great for beginners and advanced users alike!

The best pointing and tracking accuracy

With StarSense's advanced mount modeling, you can lock in up to 10 alignment stars. Your mount will achieve a new level of accuracy, centering stars in the eyepiece every time.

The fastest polar alignment procedure*

Spend less time aligning and more time astroimaging with Celestron's proprietary All Star Polar Alignment. This revolutionary alignment procedure is even quicker and more streamlined with StarSense AutoAlign.

*with compatible mounts

Shown on CPC Deluxe HD
(not included.)

CELESTRON PREMIER SELECT DEALERS

OPT Telescopes – 800.483.6287 – www.opttelescopes.com
B&H Photo – 800.947.9970 – www.bhphotovideo.com
Hands On Optics – 866.726.7371 – www.handsonoptics.com
Astronomics – 800.422.7876 – www.astronomics.com
Adorama – 800.223.2500 – www.adorama.com
High Point Scientific – 800.266.9590 – www.highpointscientific.com
Optics Planet – 800.504.5897 – www.opticsplanet.com
Focus Camera – 800.221.0828 – www.focuscamera.com
Woodland Hills – 888.427.8766 – www.telescopes.net

celestron.com

Tele Vue Eyepieces & Telescopes: Exceptional Performance, Exceptional Quality.

If you were going to the Moon, wouldn't you want to practice landing?

Al Nagler, Tele Vue founder, designed the optical system for the lunar lander training simulators used by the Apollo astronauts. Years later, that experience inspired him to design eyepieces and telescopes of extraordinary quality, one customer dubbing the view as "a space-walk experience." Visit TeleVue.com and discover how to bring the "spacewalk experience" to your backyard.

Finely crafted in America, our multi-purpose refractors are an investment in a lifetime of astronomical and terrestrial observing and photography.

We create our eyepieces to satisfy your personal preferences. Call us to custom tailor the best for your needs. So when you put a Tele Vue into your telescope, your view is"...even better than you imagined."

Tele Vue-60
60mm APO, f/6.0

Tele Vue-76
76mm APO, f/6.3

Tele Vue-85
85mm APO, f/7.0

Tele Vue-NP101
101mm, Flat-Field,
APO, f/5.4

Tele Vue-NP101is
101mm, Flat-Field,
APO, f/5.4

Tele Vue-NP127is
127mm, Flat-Field,
APO, f/5.2

Nagler T6 82° AFOV

Nagler Planetary
Zoom 50° AFOV

Ethos 100°—110° AFOV

Nagler T5 82° AFOV

Nagler T4 82° AFOV

Panoptic 68° AFOV

Plössl 50° AFOV (43° in 40mm)

Delos 72° AFOV

TeleVue® Visionary

32 Elkay Drive, Chester, New York 10918 845.469.4551 www.TeleVue.com

Online Content Code: ASY1503
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content

CONTENTS

25

MARCH 2015
VOL. 43, NO. 3

COVER: *ASTRONOMY*: CHUCK BRAASCH AND ROEN KELLY

ON THE COVER

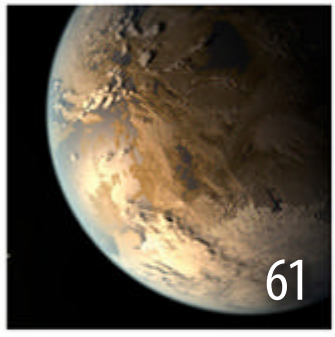
***Astronomy*'s list of the 500 coolest things about space covers all aspects of the science, from space exploration and our solar system to black holes and stellar explosions to historical milestones and technological breakthroughs.**

FEATURES

22 **COVER STORY**
We all know astronomy is cool. But have you ever sat under the stars and had a conversation about the most fascinating things in our beloved science? The editors of *Astronomy* have, and we're bringing to our readers the 500 coolest things about space.

44
The Sky this Month
Darkness at midday.
MARTIN RATCLIFFE AND ALISTER LING

46
StarDome and Path of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY



COLUMNS

Strange Universe 11
BOB BERMAN
Secret Sky 16
STEPHEN JAMES O'MEARA
Observing Basics 82
GLENN CHAPLE
Astro Sketching 84
ERIKA RIX

QUANTUM GRAVITY

Snapshot 9
Breakthrough 10
Astro News 12

IN EVERY ISSUE

From the Editor 6
Letters 11, 82
Web Talk 83
New Products 85
Advertiser Index 87
Reader Gallery 88
Final Frontier 90

Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers.

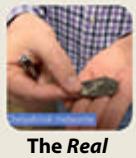
Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement #40010760.

ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

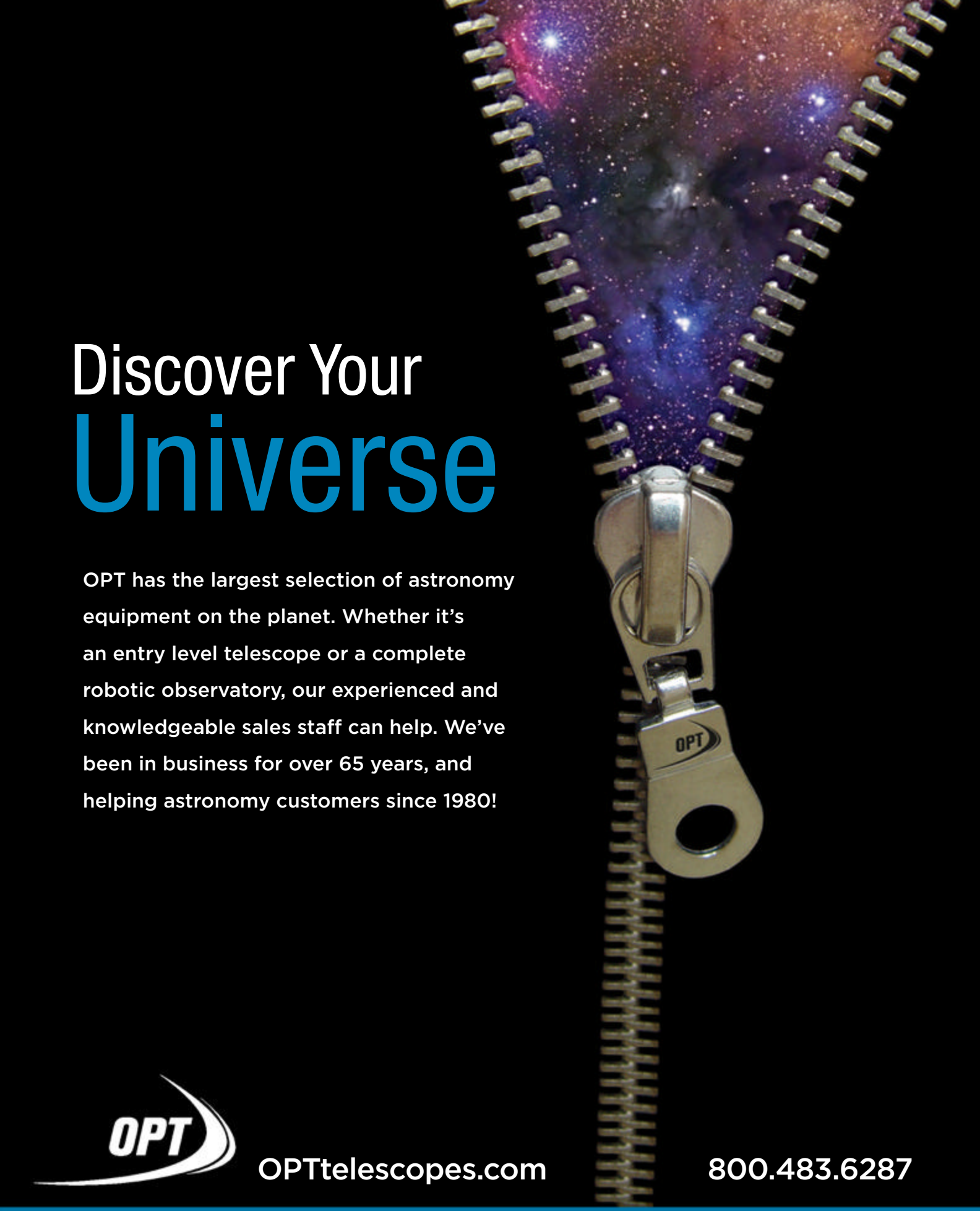
Blogs from the Local Group
Insight from the editors

Observing Basics
How to get the most from your equipment



The *Real* Reality Show
Discover the true wonders of the universe

50 Weirdest Objects
Explore the most curious cosmic oddities



Discover Your Universe

OPT has the largest selection of astronomy equipment on the planet. Whether it's an entry level telescope or a complete robotic observatory, our experienced and knowledgeable sales staff can help. We've been in business for over 65 years, and helping astronomy customers since 1980!

OPT

OPTtelescopes.com

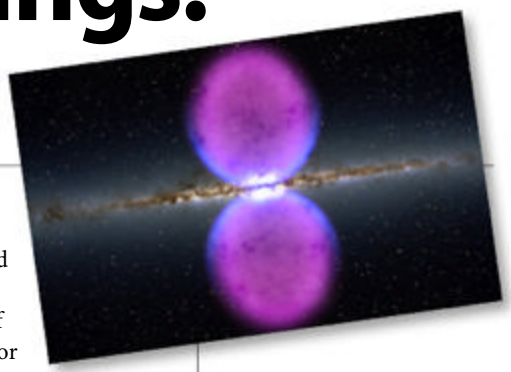
800.483.6287

Stay Tuned to OPTAS.NET for Our 2015 Photo Contest! Details coming soon.

FROM THE **EDITOR**

BY DAVID J. EICHER

500 coolest things!



A few months ago, Senior Editor Richard Talcott casually mentioned to me, "You know, March 2015 will be the 500th issue of *Astronomy* magazine." Not having thought about it, I was tickled, and Talcott proposed that we do something special for the occasion. Weeks later, our other senior editor, Michael E. Bakich, put together the basic plan for a special package of fun stuff we had discussed. The result, "The 500 coolest things about space," is what you hold in your hands.

What would make your list of 500 things? Perhaps it would be the Hubble Deep Field, the explosion of exoplanets discovered with the Kepler space telescope, or the high probability of inflation theory helping to explain the cosmos.

Maybe you're in the mood for history. Do the achievements of Albert Einstein, with his special and general theories of relativity, or the publication of *Principia Mathematica* by Isaac Newton grab you?

Perhaps you'll draw on your own cherished memories as an astronomy enthusiast or some of the coolest events you've seen in the sky as inspiration. Maybe your 1986 view of Halley's Comet would do the trick, or the 1994 collision of 21 fragments of Comet Shoemaker-Levy 9 into Jupiter. Or it could be that a cherished solar eclipse makes the list, as Americans prepare for a total eclipse event in 2017.

You might be focused on the big-picture solutions to long-standing questions in astronomy and astrophysics. You say the true nature of the Milky Way Galaxy excites you? Or perhaps the Copernican revolution of the Sun-centered solar system in 1543? Maybe you enjoy poring over the journal and sketch pages of Galileo from those first months of observing the heavens with a crude telescope.

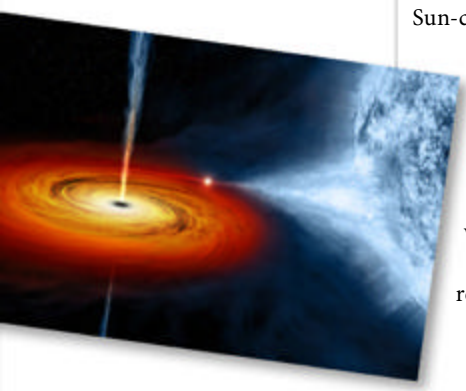
It could be that more recent discoveries dazzle you somewhat more. How about a stellar-mass black hole with a density 1 quadrillion times greater than water? Or the fact that nearly 11,000 near-Earth asteroids or comets float in the same space as our planet in the inner solar system? Or the knowledge that each minute some 100 trillion neutrinos pass through your body?

Wherever you find your most amazing moments contemplating the great universe that surrounds us, this issue is designed to bring some of that joy and wonder about the incredible complexity of it all to you.

It is my sincere hope that you will enjoy this special package of *Astronomy* magazine for a long time and come back to it every once in a while whenever your concerns here on Earth nudge you to need a little more perspective.

Yours truly,

David J. Eicher
Editor



Astronomy

Editor David J. Eicher
Art Director LuAnn Williams Belter

EDITORIAL STAFF
Senior Editors Michael E. Bakich, Richard Talcott
Production Editor Karri Ferron
Associate Editor Eric Betz
Editorial Associate Valerie Penton

ART STAFF
Senior Graphic Designer Chuck Braasch
Illustrator Roen Kelly
Production Coordinator Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Liz Kruesi, Ray Jayawardhana, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, Erika Rix, John Shibley, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Kalmbach Publishing Co.

President Charles R. Croft
Vice President, Editorial, Publisher Kevin P. Keefe
Senior Vice President, Sales & Marketing Daniel R. Lance
Vice President, Consumer Marketing Nicole McGuire
Corporate Art Director Maureen M. Schimmel
Managing Art Director Michael Soliday
Production Manager Helene Tsigistras
Corporate Advertising Director Ann E. Smith
Group Circulation Manager Ken Meisinger
Single Copy Sales Manager Michael Barbee
Marketing Specialist Cathy Muempfer

ADVERTISING DEPARTMENT
(888) 558-1544
Advertising Sales Manager Jeff Felbab
Advertising Sales Representative
Dina Johnston, djohnston@kalmbach.com
Ad Services Representative
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544, Press 3
Outside U.S. and Canada (262) 796-8776, ext. 818
Fax (262) 798-6592
Email tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (800) 533-6644; **Fax** (262) 796-1615
customerservice@kalmbach.com

SPECIAL EMAIL ADDRESSES
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com

Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: (800) 533-6644; outside the U.S. and Canada: (262) 796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 4:30 P.M. CT, Fax: (262) 796-1615; Email: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence.

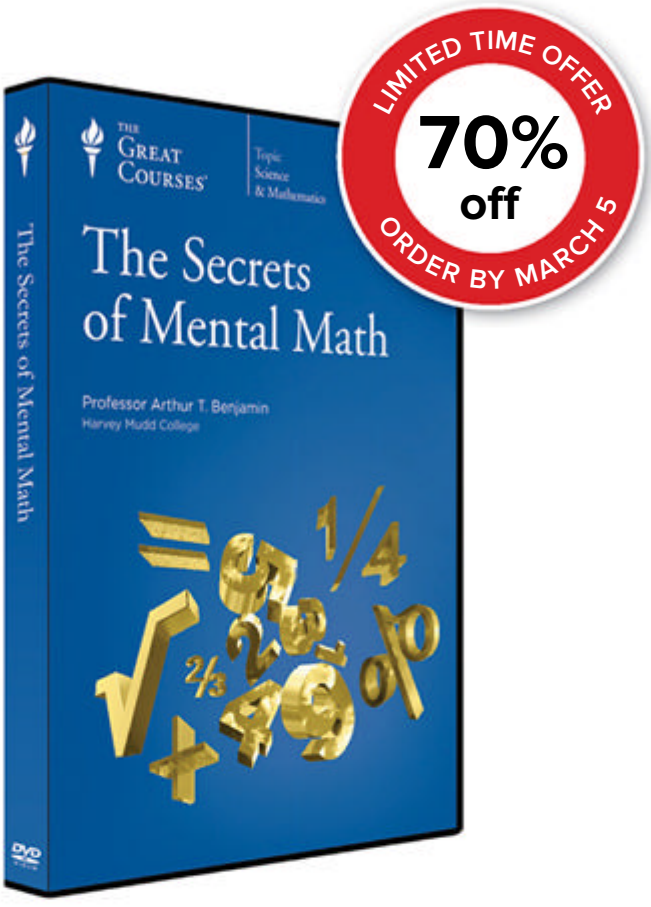
Copyright © 2015 Kalmbach Publishing Co., all rights reserved. This publication may not be reproduced in any form without permission.

Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $5.99; U.S.: 1 year (12 issues) $42.95; 2 years (24 issues) $79.95; 3 years (36 issues) $114.95. Canadian: Add $12.00 postage per year. Canadian price includes GST, payable in U.S. funds. All other international subscriptions: Add $16.00 postage per year, payable in U.S. funds, drawn on a U.S. bank. Expedited delivery service surcharges: Domestic first class $30/yr; Canadian air $30/yr; International air $60/yr. BN 12271 3209 RT. Not responsible for unsolicited materials.

Follow *Astronomy*

www.twitter.com/AstronomyMag
www.facebook.com/AstronomyMagazine
plus.google.com/+astronomymagazine

THE GREAT COURSES®



Discover the Secrets of Mental Math

One key to expanding your math potential—whether you're a corporate executive or a high school student—lies in the power to perform mental math calculations. Solving basic math problems in your head offers lifelong benefits including a competitive edge at work, a more active and sharper mind, and improved performance on standardized tests.

In the 12 rewarding lectures of **The Secrets of Mental Math**, discover all the essential skills, tips, and tricks for improving and enhancing your ability to solve a range of basic math problems right in your head. Professor Arthur T. Benjamin, winner of numerous awards from the Mathematical Association of America, has designed this engaging course to be accessible to anyone looking to tap into his or her hidden mental calculating skills.

Offer expires 03/05/15

THEGREATCOURSES.COM/6ASTR

1-800-832-2412

The Secrets of Mental Math

Taught by Professor Arthur T. Benjamin
HARVEY MUDD COLLEGE

LECTURE TITLES

1. Math in Your Head!
2. Mental Addition and Subtraction
3. Go Forth and Multiply
4. Divide and Conquer
5. The Art of Guesstimation
6. Mental Math and Paper
7. Intermediate Multiplication
8. The Speed of Vedic Division
9. Memorizing Numbers
10. Calendar Calculating
11. Advanced Multiplication
12. Masters of Mental Math

The Secrets of Mental Math
Course no. 1406 | 12 lectures (30 minutes/lecture)

SAVE $160

DVD ~~$199.95~~ **NOW $39.95**
+$5 Shipping, Processing, and Lifetime Satisfaction Guarantee
Priority Code: 110112

For 25 years, The Great Courses has brought the world's foremost educators to millions who want to go deeper into the subjects that matter most. No exams. No homework. Just a world of knowledge available anytime, anywhere. Download or stream to your laptop or PC, or use our free mobile apps for iPad, iPhone, or Android. Over 500 courses available at www.TheGreatCourses.com.

Huge Rebates on Vixen Telescope and Mount Packages

Rebates up to $700!

For over 65 years Vixen has been synonymous with high quality precision optics and innovative Go-to Mounts. Whether you choose the VMC200L and Sphinx SX2 Mount or the AX103S Refractor and Sphinx SXP Mount, you can be assured of great views and highly accurate tracking. Check out these Rebates on our most popular packages

	Price	Rebate	Your Cost
Sphinx SX2 and A80M	$2599	$300	$2299
Sphinx SX2 and VMC200L	$3499	$350	$3149
Sphinx SXD2 and ED103S	$4999	$500	$4499
Sphinx SXP and VC200L	$5699	$500	$5199
Sphinx SXP and AX103S	$6999	$700	$6299

See the full list at vixenoptics.com

When Quality Matters, Vixen Mounts and Scopes are the Clear Choice. Vixen Optics

March 2–11, 2016

Tour BALI and witness a TOTAL ECLIPSE

with *Astronomy* magazine

Experience a solar eclipse trip like no other in the equatorial paradise of Indonesia. Immerse yourself in the festivities leading up to the Balinese New Year before watching the Moon block the Sun's light in a total solar eclipse. Your tour includes:

- Balinese rituals that few ever witness
- Visits to stunning ancient temple gardens
- Lectures and eclipse viewing guidance from *Astronomy* staff
- And much more!

JOIN THE TRIP TODAY!

Visit www.astronomy.com/bali

Astronomy magazine

TRAVEL QUEST International

P24157

William Cho (landscape); Mike Reynolds (eclipse)

QG QUANTUM GRAVITY

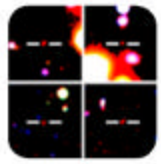
EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES >>

TRENDING TO THE TOP

BINARY EARTHS?
A Caltech undergrad used a weeklong computer simulation to show dual rocky planets could remain stable sci-fi style in a tidally locked orbit.

CERES APPROACH
The Dawn spacecraft shot its best Ceres image yet as NASA calibrated the craft's camera for a spring asteroid approach and orbital insertion.



FIRST GALAXIES
A survey of the early universe found seven galaxies from a group scientists believe suddenly appeared 700 million years after the Big Bang.

SNAPSHOT

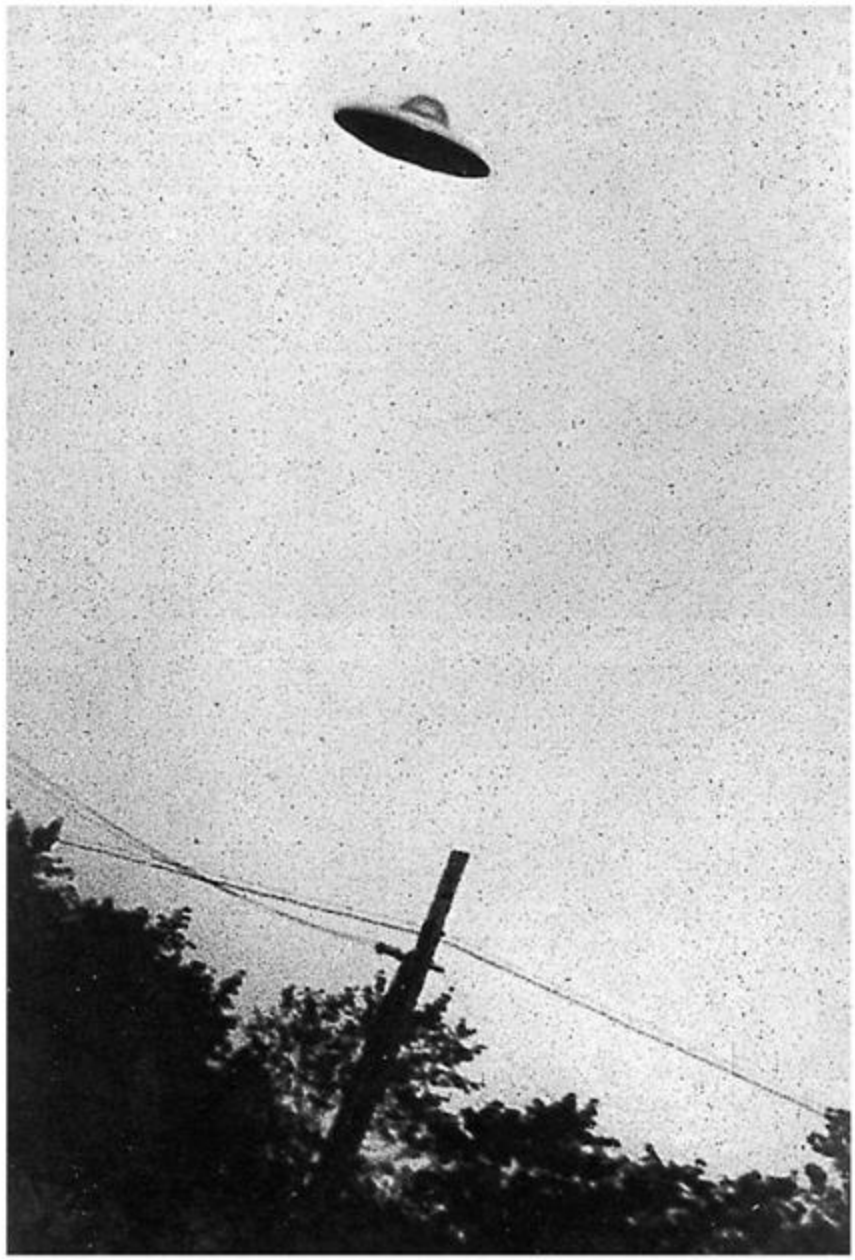
Let's cut the UFO crap

Belief in alien visits equals incredible naiveté about the cosmic distance scale.

The efforts now underway to search for extraterrestrial civilizations invariably raise the favorite question of many TV shows: Has alien life visited Earth in the form of UFOs? After all, half the American public believes alien beings have visited our planet. The claims of UFO proponents, when actually subjected to the principles of scientific analysis, are not very strong. Reports of UFOs commenced in earnest just after World War II with a well-publicized incident near Mount Rainer and the claims of a businessman who said he spotted nine shiny "flying saucers" moving at high velocities. But the thousands of UFO reports made since, many of which have been thoroughly and scientifically investigated, have yielded nothing about the existence of life elsewhere in the universe. People see things in the sky they often don't understand. That's the conclusion.

The fact that observers can't identify an object, or that it seems mysterious to them, should not be surprising — particularly given the nature of some of the reports. The "unidentified" part of the term UFO does not mean turning over all we know about science, about the physics of spacecraft and the cosmic distance scale, about Occam's Razor, and leaping right into alien visitation.

Face it, folks, it's a very big universe. But that gives us a little perspective, if nothing else. Earth is a pretty special place, at least for our species, and we should take good care of it, our fellow human beings, and everything else that lives along with us. It's the only home we have. **— David J. Eicher**



Of many thousands of UFO reports since sighting flying saucers became fashionable in the late 1940s, not one has had a shred of scientific credibility.

CIA STUDIES IN INTELLIGENCE, NO. 1, 1997 (FLYING SAUCER); NASA/JPL-CALTECH (BINARY EARTHS?); NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA (CERES APPROACH); ICRR, UNIVERSITY OF TOKYO, NAOJ (FIRST GALAXIES)

Blast from the past

The supernova remnant Kes 73 in Scutum shows what can happen when a star holding more than 20 solar masses reaches the end of its life. In this case, a cataclysmic explosion ripped the star's outer layers apart, sending debris racing outward. Meanwhile, the massive sun's core collapsed into a pulsar (the blue dot at center) that energizes the expanding shell of gas. Kes 73 lies about 28,000 light-years away, and light from the explosion likely reached Earth between 750 and 2,100 years ago. This image combines visible light (grayscale), X-rays (blue), infrared radiation (orange), and radio waves (red). X-RAY: NASA/CXC/UNIVERSITY OF MANITOBA/H. KUMAR, ET AL.; VISIBLE: DSS; INFRARED: NASA/JPL-CALTECH; RADIO: NSF/NRAO/VLA

STRANGE**UNIVERSE**

BY BOB BERMAN

Adventures in terra incognito

What to do when you're lost in space.

Ever been lost? Camped out and couldn't remember which trail you'd taken? Driven around at night in some bad neighborhood trying to figure out how to get back on the highway? It's worse if you're piloting a plane and have no clue where you are. I've done it all. Only slightly less perilous is to be lost in space.

No human has yet gone astray between worlds. But Buzz Aldrin came close during the final Gemini mission, when the navigation computer went on the fritz. Figuring out how to manually get all the way to the invisible, high-orbit target Agena rocket through calculations alone solidified his "Dr. Rendezvous" nickname and may have earned him that coveted spot on Apollo 11.

Some inanimate object was lost, too, back in 1969 during the Apollo 12 mission. For days, the crew watched a large, distant tumbling object out their window that kept pace with them on their way to the Moon. "We'll assume it's friendly," quipped Dick Gordon. Nothing was supposed to be there. To this day, no one is sure what it was.

A couple of robots have gotten lost much farther away — at Mars. On August 21, 1993, when the Mars Observer spacecraft reached the Red Planet's vicinity, all contact was suddenly lost. What happened? No one ever decisively figured it out. The craft might have obeyed its onboard computer instructions, and maybe it's still orbiting Mars today. More likely a fuel line blew, with the spray making the craft spin crazily. It may have crashed, or perhaps it's orbiting the Sun.

For us as observers, getting lost more commonly means gazing into a gorgeous rural firmament and having no idea what we're seeing. These nights, not too many backyard astronomers know all that stuff beneath Orion that constitutes Lepus the Hare and Eridanus the River to its right. Even worse are the faint enigmatic overhead patterns of Lynx the Lynx and Camelopardalis the Giraffe.

I'm one of those half-idiot people who can't remember faces but never forget numbers and such. At age 14, I memorized every named star along with their distances and spectral classes. And π to 80 places. You know people like that; maybe you're one of them. Part of it ended up being useful. But I still get disoriented. Plopped on the Falklands at an unaccustomed season, my first reaction is, "Whoa, wait a minute …"

GETTING LOST AMONG THE STARS IS ACTUALLY A WONDERFUL THING. IT CONJURES A SENSE OF INFINITUDE.

Getting lost among the stars is actually a wonderful thing. It conjures a sense of infinitude. And, hey, don't we all need periodic vacations from our logical minds? The stars are epic and soothing when you *don't* know their Greek letter labels. Anyway, you'll hear no romantic sighs when you point out constellations like "the fly" and "the stern," Musca and Puppis.

Ironically, professional astrophysicists are the ones who get lost most easily in the real night sky. Many do *not* know the constellations, with some notable exceptions. But astronauts do. A few, like winsome Andy Thomas, who grew up in the Outback and spent nearly half a year cumulatively in space, know the sky really well. Fanatics who *truly* know the heavens have a lot of fun. They never need charts to locate Messier objects.

But go to Chile or New Zealand, and it's a new ball game. Everything's upside down. Huge vacant swatches around Tucana the Toucan and Fornax the Furnace become terra incognito. After some basic star-hopping from Crux the Cross or the Magellanic Clouds, I go, "OK, there's Canopus and the False Cross and, wow, OK, Fomalhaut — high up instead of low like back home," and I'm soon reoriented enough to lead a group who knows even less. A decade ago, I had to memorize that southernmost quarter of the firmament from scratch, with a brain containing 10 percent fewer neurons than before college.

Learning the sky is a venerable pastime. There's not much ego: Everyone knows that the cosmos is basically made of magical mystery material. Anyway, only some five dozen stars still have names in common use, so it's actually not hard to identify them all. Yes, every star. Maybe 200 if you include the fainter Bayer designations. Tackle one constellation per night. Got the time? Out of good books to read? (Don't forget my latest, *Zoom*.) Are you in or out?

And when we meet someday, share what you know, and we'll enjoy the ancient scene together, laughing about some of the odd stories and curious pronunciations. And if some faint patch makes us both wonder, "Is that still Aquarius, or is it part of Pisces?" we can smile and shrug. Just as people have done for millennia when they've been lost in space.

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

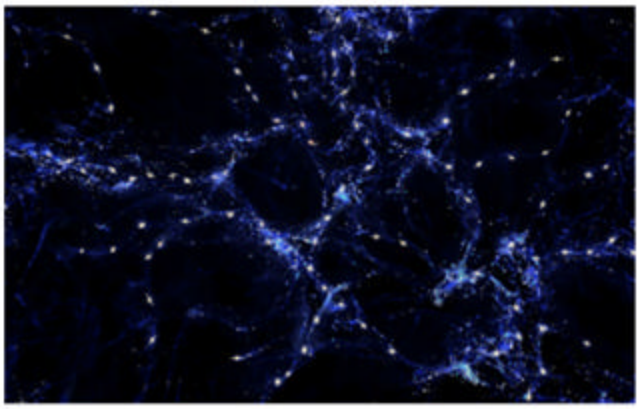
Be an inspiration

I was moved to write by David J. Eicher's editorial at the front of the October 2014 issue (p. 6). My grandmother introduced me to astronomy. She gave me a 2.5-inch refractor when I was 13, and I was hooked. I used lawn-mowing money to buy science-fiction books, record albums, and my first *Astronomy* subscription in 1974. So, to Eicher's very important point, how do we inspire children of today to step outside and explore the real world that is above them? Clearly there needs to be mentorship like I received or maybe even benevolent kidnapping to get them out of doors. For the kids who take the bait and begin to seek information on their own, your magazine consistently delivers. **— Mark Gibbs,** Lake Elsinore, California

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

ALIEN MAGNETISM. Russian scientists developed a method to measure the magnetic field of an exoplanet and applied it to the hot Jupiter HD 209458b (Osiris), the first outside our solar system known to have an atmosphere.



DISTANT PATTERNS. Astronomers have uncovered that the rotation axes of active galaxies' central supermassive black holes are aligning with the cosmic web filaments on which they lie, as illustrated in this artist's impression. ESO/M. KORNMESSER

ACTIVE BLACK HOLES ALIGN

While studying the active centers of distant galaxies using the Very Large Telescope in Chile, astronomers stumbled upon a surprising pattern: Nineteen of these 93 quasars, which are supermassive black holes surrounded by spinning disks of material that often shoots out in jets along their rotation axes, were lining up across great distances when the universe was one-third of its current age.

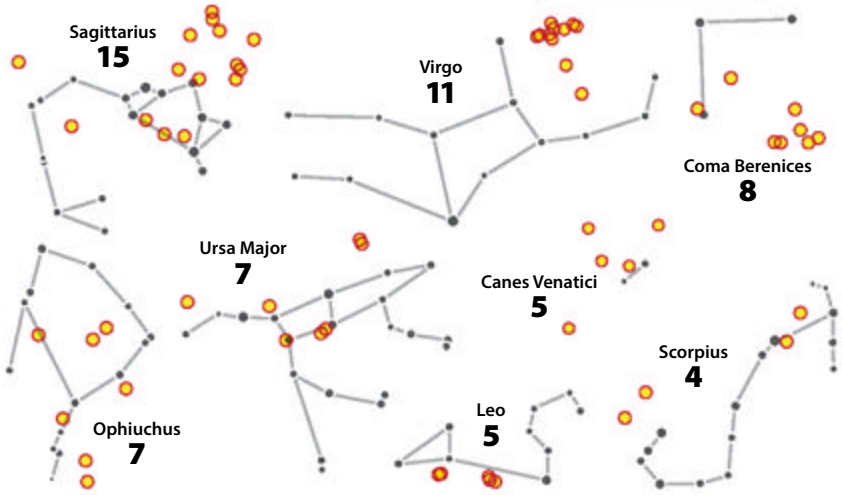
"The first odd thing we noticed was that some of the quasars' rotation axes were aligned with each other despite the fact that these quasars are separated by billions of light-years," says lead author Damien Hutsemékers of the University of Liège in Belgium. So he and his team went further to see if the alignment also linked to the largest structures in the universe, the cosmic web along which all galaxies appear to lie. The result, which appeared in the November 19 issue of *Astronomy & Astrophysics*, shows that the quasars' rotation axes are generally parallel to the cosmic web filament on which their galaxies reside. The chance of such an alignment being a coincidence is less than 1 percent.

According to co-author Dominique Sluse of the University of Bonn in Germany, "The alignments in the new data, on scales even bigger than current predictions from simulations, may be a hint that there is a missing ingredient in our current models of the cosmos."

— Karri Ferron

CONSTELLATIONS WITH THE MOST MESSIER OBJECTS

Only 34 of the 88 constellations contain Messier objects. FAST FACT



NORTHERN BIAS. The list of 109 objects compiled by French comet hunter Charles Messier contains many of the finest deep-sky treats. Messier, however, observed from Paris, so the far-southern sky was lost to him. That's why 62 of his objects lie in just these eight constellations. *ASTRONOMY*: MICHAEL E. BAKICH AND ROEN KELLY

BRIEFCASE

COSMIC CRASH STOPS STAR BIRTH

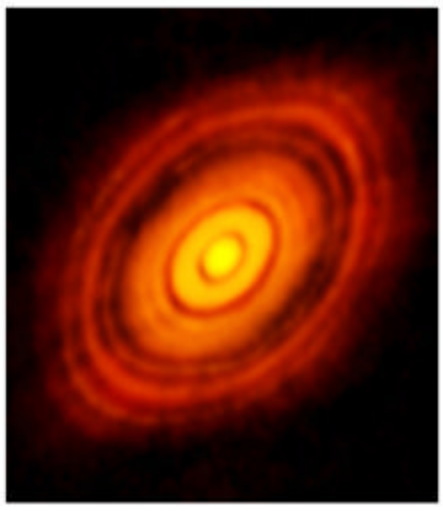
A new spectroscopic instrument on the Very Large Telescope in Chile has shown how star formation shuts off in galaxies within clusters. Astronomers used the instrument's unprecedented motion data to catch a gas-rich galaxy, dubbed ESO 137-001, while it was being stripped of star-forming material as it rammed into the Norma Cluster at high speed.

STELLAR SYSTEMS SEEN FORMING

A young star with four directly imaged exoplanets has now been seen to have two disks of debris, similar to the asteroid and Kuiper belts in our solar system, as well as a surrounding dust halo. Similar features were also found around another star, prompting astronomers to dub the star system images "baby photos."

STRANGE STAR OR BLACK HOLE EVICTION?

When two galaxies collide, their supermassive black holes do too. But astronomers studying such mergers have stumbled upon what might be a supermassive black hole that was ejected instead and sent soaring 2,600 light-years from its host galaxy's core. However, the bizarre object also could be the remains of a massive star gone supernova, the researchers say. To test this, the team tracked the object through 60 years of data but found no clear indications. **— Eric Betz**



ALMA (NRAO/ESO/NAOJ); C. BROGAN, B. SAXTON (NRAO/AUI/NSF)

ALMA glimpses planet formation

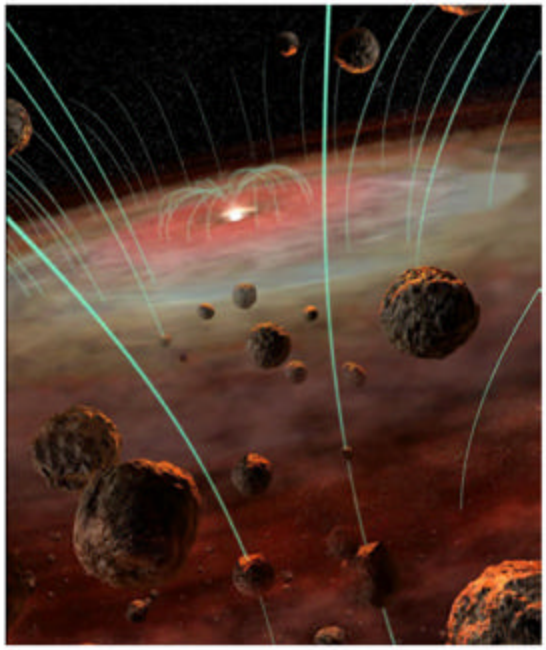
INTERIOR INVESTIGATION. The Atacama Large Millimeter/submillimeter Array (ALMA) has provided scientists with their best look ever at a planet-forming disk around a young star. During the new instrument's testing phase, in which its 66 antennas were as far as 9 miles (15 kilometers) apart, it peered past the massive envelope of gas and dust surrounding the star HL Tauri and captured an image that showed multiple rings separated by clear gaps around the infant sun. Such a configuration suggests planet formation is already occurring in this system, which surprised scientists because HL Tauri is only about a million years old, too young to be this far in the process — or so astronomers thought. ALMA will continue to provide more insight into planet formation as it produces even more detailed images in the future. The observatory released this image November 6. **— K. F.**

NEW HORIZONS WAKES. NASA's New Horizons spacecraft woke from hibernation December 6 as it began the final leg of its mission to Pluto. Closest approach to the dwarf planet is planned for July 14.

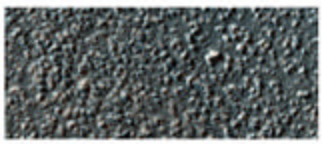
Meteorite reveals new clues about solar system beginnings

Although astronomers have a general theory of how the solar system formed, many mysteries remain. One way to investigate what was happening around the infant Sun is to study meteorites that arrive on Earth today. Chondrites, which are pieces of asteroids, are the most primitive type of meteorite and remain essentially the same as they were when the solar system formed, so they can provide valuable information about the early solar system and the solar nebula from which the planets, asteroids, and comets formed.

In a study published November 13 in *Science*, astronomers made an unprecedented measurement of the magnetic fields trapped in the grains that make up the Semarkona meteorite, a chondrite that fell to Earth in 1940. These millimeter-sized chondrules formed in the solar nebula from quick heating and then cooling events, and they preserve the local magnetic fields of the surrounding gas. Modeling based on the magnetic field measurements indicates that shock waves passing through the solar nebula caused the dust grains to melt before cooling into chondrules in an area that corresponds to today's asteroid belt. **— K. F.**



MAGNETIC MEASUREMENT. By studying tiny grains in a meteorite, scientists made the first reliable measurement of the magnetic field of the disk of material from which our solar system formed.
HERNÁN CAÑELLAS/MIT PALEOMAGNETISM LABORATORY



NASA/JPL/UNIV. OF ARIZONA

EARLY ERUPTIONS. Astronomers believe this "knobby terrain" on the Red Planet resembles earthly features that are formed with pyroclastic ash.

Explosive eruptions rocked early Mars

Planetary geologists say the martian crust is weak because it's composed of fine sediments left by volcanoes that sluggishly oozed lava early in the Red Planet's history. But in recent years, the remains of ancient, once explosive volcanoes have been spotted, providing contradictory evidence that Mars' surface might have pyroclastic origins.

Chinese astronomers have piled on evidence for early explosive eruptions with a sweeping analysis of 75 martian volcanoes in the journal *Geophysical Research Letters*.

They found that 17 of the volcanoes had a unique type of "knobby terrain" nearby. The authors compare the terrain to ignimbrites on Earth, which form after explosions of pyroclastic ash and rock sweep down volcanoes. If these knobby features formed the same way, it's a sign that some of Mars' crust could have been created by massive deposits of ash. **— E. B.**

Orion makes flawless first flight

The first spacecraft capable of carrying humans beyond low Earth orbit since Apollo 17 made a near-perfect maiden voyage December 5. NASA's Orion spacecraft shot up some 3,600 miles (5,800 kilometers) above Earth's surface, breaching the Van Allen radiation belts, before safely landing right on target in the Pacific Ocean.

MAIDEN VOYAGE. NASA's Orion spacecraft performed perfectly in December. NASA

Along the way, its propulsion and heat shield performed perfectly despite damage NASA intentionally inflicted by drilling into the heat shield to test the craft as it hit speeds around 20,000 mph (32,000 km/h) and reentry temperatures that reached in excess of 4,000° F (2,000° C).

Two of the capsule's five air bags didn't deploy as Orion splashed into the Pacific, but the craft stayed upright regardless.

NASA hopes that the craft — which resembles Apollo but carries more modern computers and navigation — will one day carry astronauts beyond the Moon to capture an asteroid, or even on to Mars. At present, however, there is neither the funding nor capability to do either.

The next unmanned launch of Orion will take place in 2018, when it will soar atop the $12 billion Space Launch System — the largest rocket humanity has ever built — and then rendezvous with the European Space Agency's Orion Service Module. The first Orion flight with people on board is scheduled for 2021, when NASA plans to visit the Moon Apollo 8-style, orbiting around and then returning to Earth.

The cost for Orion leading up to that first piloted flight is estimated at some $10 billion, according to the Government Accountability Office, with significantly more needed to develop additional vehicles and rockets down the road. The agency has not developed a Mars lander or habitat, however; the space agency maintains that when it sends humans to the Red Planet in the 2030s, they will be riding in an Orion capsule. **— E. B.**

QUICK TAKES

ANARCHISTIC YOUTH

Astronomers used Hubble to create the largest survey yet of disks around young stars, finding unexpected complexity as material is ejected and planets collide in these chaotic systems.

CAPTURING CORES

Scientists published the first paper from the Large Millimeter Telescope in Mexico — built to study distant galactic cores — showing the relationship between star formation and dust clouds around galaxies.

EARTH TO VENUS

The European Space Agency lost contact with Venus Express in November after the craft dipped down into that planet's atmosphere seeking new insights as the mission ends. Officials suspect the maneuver used the last bits of fuel.

ASTEROID SIZE-UP

The double asteroid Patroclus-Menoetius passed in front of a star in October, allowing an accurate measurement of the rocks' sizes and shapes. Prior data indicated each body was spherical, but the occultation showed distinct oblong forms.

THE TWO TOWERS

A team used the Keck Observatory Interferometer's twin telescopes to nail down a new way to find precise galactic distances and tested it on the "Eye of Sauron" to show the active supermassive black hole is 60 million light-years away.

ASTEROID LANDER 2.0

Japan's Hayabusa 2 launched December 3 for a one-year asteroid study and sample return mission to begin in 2018. Its predecessor landed on asteroid Itokawa in 2005 and returned a sample to Earth in 2010.

JUPITER'S SUNBURN

Cassini data show Jupiter's Great Red Spot forms as the Sun breaks apart chemicals in the atmosphere. The find implies the red material isn't upwelled from deep below.

CLUSTER CONFUSION

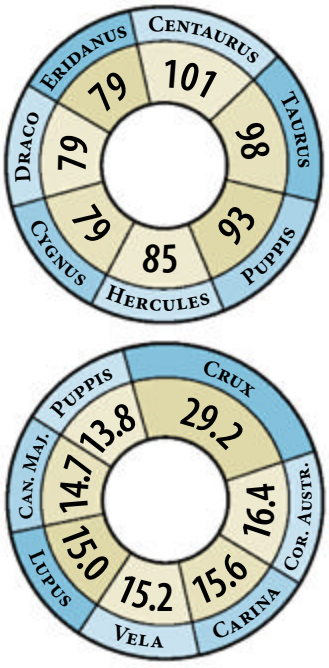
Astronomers added confusion over the Milky Way's missing globular clusters. It was once thought the star groups shared the same population and age, but Hubble observations show the globulars pack multiple generations of stars. **— E. B.**

OORT OBSERVATIONS. Astronomers used telescopes in Hawaii to catch the first images of the surfaces of Oort Cloud comets. The two newfound objects were strangely inactive, allowing instruments to get a glimpse without an interfering comet tail.

FAST FACT

The constellation Caelum has the fewest stars brighter than magnitude 5.5 with four; Sextans has the lowest stellar density with 1.6 bright stars per 100 square degrees.

THE STARRIEST CONSTELLATIONS



NUMBER VS. DENSITY. Even a casual observer of the night sky notices that stars clump together in some regions but avoid others like the plague. These pie charts compare the seven constellations with the most bright stars (top) to the seven with the highest density (stars per 100 square degrees). The cutoff is magnitude 5.5, which typically represents a dark suburban sky. Bigger constellations tend to have more stars, while smaller ones located near the Milky Way tend to win the density prizes. There isn't much overlap — only Puppis shows up on both lists.

ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY

1.23 million mph (550 km/s)

The speed necessary to escape our galaxy's gravity

SPACE SCIENCE UPDATE

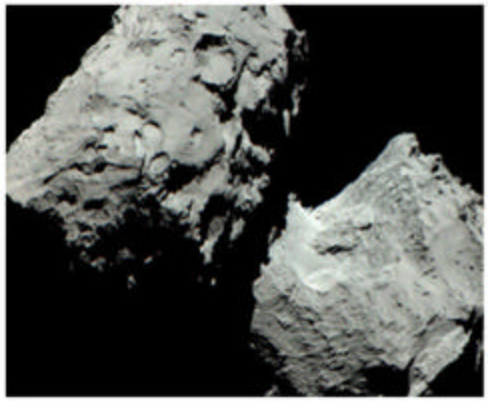
ROSETTA RACES TOWARD THE SUN

The European Space Agency (ESA) angled Rosetta ever closer to Comet 67P/Churyumov-Gerasimenko by firing its thrusters in early December, bringing the spacecraft within about 12 miles (20 kilometers) of the surface. By February, mission managers plan to enter a breathtakingly close orbit some 4 miles (6km) above the icy body. The science team says they're trying to gather the best possible images while it's still safe to approach.

"The desire is to place the spacecraft as close as feasible to the comet before the activity becomes too high to maintain closed orbits," says Rosetta Science Operations team member Laurence O'Rourke. "This 20-kilometer orbit will be used by the science teams to map large parts of the nucleus at high resolution and to collect gas, dust, and plasma at increasing activity."

ESA is calling this the "escort phase" of the mission, as Rosetta accompanies its comet on an intense journey toward the Sun. 67P will heat up the closer it gets, and an atmosphere will be created, as frozen gases are activated and kick off particles from the comet's nucleus. This coma will force Rosetta to back off and watch as a tail emerges, drifting millions of miles into space.

And while the Sun's increased illumination could be hazardous to Rosetta, mission managers believe there's a chance it might be enough to wake its companion from hibernation and allow it to resume experiments. The Philae lander's batteries died after a short, furious science mission on the comet's surface. ESA scientists now think that Philae grazed a crater rim or other surface during its descent, which sent the little lander spinning. The craft was still able to touch down on three legs, but came to rest against a cliff and is shrouded in shadow. By year's end, scientists remained uncertain where its journey concluded.



ESA /ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

SHADES OF GRAY. New Rosetta images show Comet 67P/Churyumov-Gerasimenko would appear gray to human eyes.

There was one bright spot in the chaotic descent; Philae landed not once, but three times (including a 2-mile-high [3km] bounce), allowing mission managers to collect and analyze samples from multiple spots on the comet. The Ptolemy experiment was able to sniff for organic materials, as scientists have long suspected Earth's organics might have originated in comets like 67P. Each sniff showed abundant water, but only the one taken at the initial landing site uncovered rich organics. A final sample was analyzed using an on-craft oven right before Philae lost power.

And even the bounce itself is telling experts something about the comet. Scientists believe the lander hit an unexpected hard pack of ice crusted over by a process called sintering, which happens when a surface is heated and compacts, but doesn't actually melt. — **E. B.**

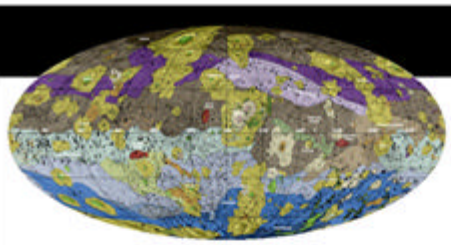
Astronomy accepting submissions for $2,500 outreach award

2014 Astronomy magazine Out-of-this-world public program

Astronomy magazine will present its 2014 Out-of-this-world Award to a club or organization anywhere across the globe that has demonstrated excellence in astronomy outreach activities. The annual $2,500 award focuses on ongoing programs by a nonprofit educational or civic organization and recognizes a group's sustained and successful efforts to involve its local community in the science and hobby of astronomy. The prize money is to be used for future astronomy outreach activities. *Astronomy*'s editors will review each entry and select a winner.

The 2013 award went to the Louisville Astronomical Society in Kentucky, which distinguished itself with the amount of outreach its members are able to do with their Urban Astronomy Center, including 96 events in 2013 that reached 6,053 people.

The official rules and entry form for *Astronomy*'s 2014 Out-of-this-world Award are available for download at www.Astronomy.com/award. Applications and material must be postmarked by February 27, 2015. The winner will be announced March 30. Further questions can be addressed to mbakich@astronomy.com.



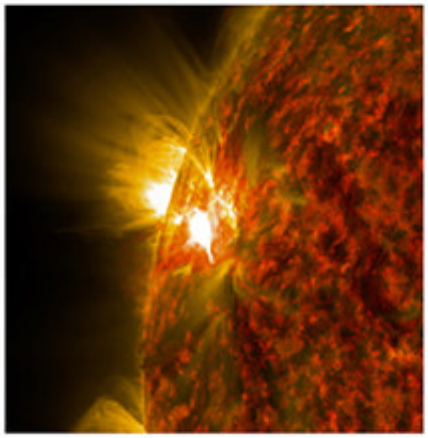
NASA/JPL-CALTECH/ARIZONA STATE UNIVERSITY

RELIC REVISITED. A fresh map of Vesta shows how impacts have constantly reshaped the asteroid's surface.

New theory rewrites Vesta's origins

In its most pure form, science follows evidence despite an observer's pre-existing bias, and scientists change their minds in light of new finds. But scientists are also human. In November, Jesuit astronomer and monk Guy Consolmagno gave a talk about such scientific flexibility at the University of Arizona. The next day, he put it into practice, admitting he erred 40 years ago when he proposed that the massive asteroid Vesta was an intact protoplanet and the source for a specific class of meteorites. The theory is the stuff of textbooks today. And those results appeared to have been confirmed by NASA's Dawn mission in recent years.

But at the Division for Planetary Sciences meeting in Tucson, Consolmagno said that instead, he and a group of international scientists have found an explanation that better fits the evidence. The team used data from Dawn that suggests Vesta was reshaped in a massive collision sometime in the past, meaning it does not date to the solar system's formation. Based on reaction at the meeting, some astronomers still believe he was right the first time. — **E. B.**



NASA/SDO

Sun roars back to life

STAR BURST. The Sun was a stormy place through fall, as the once declining high point of our solar cycle appeared to linger on. NASA's Solar Dynamics Observatory captured this active region, dubbed AR 12205, in extreme ultraviolet light November 5 after the Sun sent out a pair of midlevel solar flares. The above flare was rated M7.9, placing it at one-tenth the strength of an intense X-class flare, which the Sun later released in December. Thanks to Earth's magnetic field, a flare's radiation is harmless to humans but can disrupt satellites and even black out radio signals. One positive impact for earthbound observers: The aurorae borealis returned strong as nights grew longer in the Northern Hemisphere. — **E. B.**

Simplify your CCD imaging

- Tru-Balance LRGB imaging filters
- 3 and 5 nm narrowband filters (H-a, OIII, SII, NII)
- 100% coated Sloan & UVBRI photometric filters
- MOAG, MonsterMOAG off-axis guiders
- TAKometer remotely-controlled camera rotator

Astrodon® www.astrodon.com

www.Vernonscope.com

BRANDON EYEPIECES

- 6-48mm focal length
- Ultrasharp
- Superior contrast
- American made

vernonscope@gmail.com

Introducing the Paramount MYT

With Paramount performance in a grab and go mount, let the Paramount MYT be a trusted companion in all your digital imaging pursuits. At $6,000, the Paramount is now within reach. Grab yours today.

bisque.com

SB SOFTWARE BISQUE

PORTABLE ROBOTIC MOUNT MYT

© 2015 Software Bisque, Inc. All rights reserved.
862 Brickyard Circle Golden, Colorado 80403
www.bisque.com

SECRETSKY

BY STEPHEN JAMES O'MEARA

The 13th "sign"?

Let's have a rational discussion about astrology.

On September 27, Mars sailed past its rival star, Antares, in Scorpius. Two days earlier, it had slipped into Ophiuchus the Serpent-bearer. "Ah, there's Mars in the zodiac's 13th sign," I beamed — until those words gave me pause. Was I sure Ophiuchus is an astrological sign? Or was I just parroting what someone had told me?

The fact is, I wasn't sure about either. So I did some research, and here's what I've learned. Granted, it's just the tip of a hefty-sized iceberg, but these basic facts helped me sound informed in my discussions about astrology.

Ptolemy's model

The second-century A.D. Greek-born Egyptian astronomer Claudius Ptolemy — creator of the geocentric model of the universe and author of *Almagest* (the most influential work on astronomy for more than 1,500 years) — also wrote *Tetrabiblos* (c. 150), the most popular astrological treatise of antiquity.

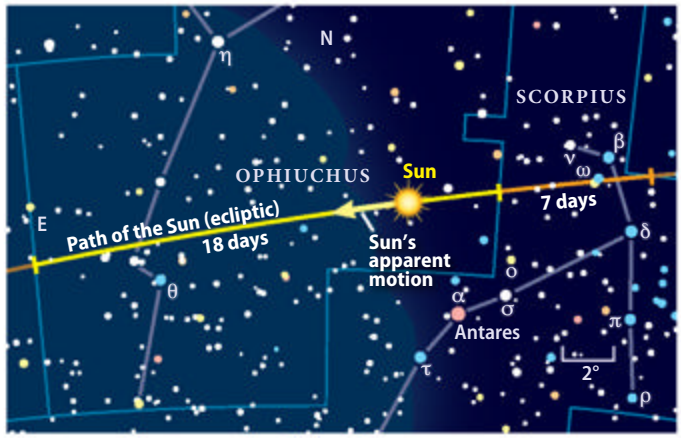
Ptolemy instituted the system of tropical astrology, one of two types. The other, sidereal astrology, divides the zodiac into 12 signs based on star positions. Tropical astrology blossomed from more ancient beliefs dating to the sixth century B.C. in Babylon (where the concept of the zodiac originated).

It ignores the stars and uses the March equinox as its starting point for the divisions. Most Western astrologers still base their predictions on Ptolemy's tropical system.

Signs

Ptolemy's system divided the ecliptic into seasonal signs — each a 30° segment structured around four celestial points: the March equinox, the June solstice, the September equinox, and the December solstice. Each season has a beginning, middle, and an end, so there are 12 zodiacal signs.

"Although there is no natural beginning of the zodiac, since it is a circle," Ptolemy wrote in *Tetrabiblos*, "they assume that the sign which begins with the vernal equinox, that of Aries, is the starting-point of them all."



The ecliptic (the Sun's apparent path through the stars) passes through Scorpius and Ophiuchus. Astronomically, the Sun spends a scant seven days "in" Scorpius compared to 18 days within the boundaries of Ophiuchus. *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

No precession?

While Ptolemy made Aries the first zodiacal sign (because that's where the vernal equinox lay at the time), the star pattern was inconsequential to his astrology. Signs were just a way to meter out the seasons.

Ptolemy was well aware of precession because he'd noted changes between earlier star charts and his observations. His astrology, however, was not affected by it.

Remove the stars from the sky, and call the first astrological sign "Alpha," and Ptolemy's tropical system around a seasonal zodiac still works. The first sign will always be the initial 30° slice of zodiac measured from the vernal equinox (whatever constellation that point appears against).

A 13th sign?

Ptolemy also knew about Ophiuchus. In fact, he included the constellation as one of the original 48 in his authoritative list. Alas, since Ptolemy's tropical system did not incorporate the fixed stars into his astrology, he didn't make Ophiuchus a member of the zodiac.

End of story? No, because some Western astrologers and most Eastern ones use a non-standard system based on the sidereal zodiac, which does consider positions of the constellations and fixed stars. Even then, Ophiuchus is not part of the system even though the Sun, the Moon, and planets pass through it. One argument is that, as with tropical astrology, sidereal signs span 30° and evenly divide into 12 zodiacal constellations.

The problem is that a tiny fraction of sidereal astrologers define their signs by the actual width of individual constellations. These astrologers (minority as they are) do recognize Ophiuchus as a 13th sign.

This issue has caused intense debate among astrologers. But there's no need to get involved. That is unless you were born under the sign of Ophiuchus (November 30 to December 17). According to some astrologers, you may "need to be involved in professional situations in which things are always changing and new advances are always coming along."

The choice, as always, is yours. Send me your astronomical thoughts at sjomeara31@gmail.com.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Eric Betz**

Cold as space — Supernova hot

Stinky science

A Swiss university press release touts the "perfume" of the Rosetta mission's comet, which has the arousing aroma of rotten eggs, urine, and formaldehyde. Don't get close to that PR guy.

Han shot first

Polish physicists with too much free time set up a laser in a hallway to record what its projectile would actually look like. It turns out space war is more boring than even *Revenge of the Sith*.

Ground control

After negotiations with David Bowie, Canadian astronaut Chris Hadfield's sensational "Space Oddity" rendition, made while actually floating in a tin can, is back on YouTube. 100,000 miles isn't enough to escape copyright lawyers.

Papal physics

American media freaks when Pope Francis says the Big Bang doesn't contradict divine creation, drawing yawns from Vatican astronomers keen to point out it was a Jesuit priest's idea in the first place.

ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA (STINKY SCIENCE); IPC PAS, GRZEGORZ KRZYŻEWSKI (HAN SHOT FIRST); CHRIS HADFIELD/NASA/CSA (GROUND CONTROL); KATHOLIEKE UNIVERSITEIT LEUVEN (PAPAL PHYSICS)

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

The Formation Of Water And Our Solar System From A Fission Process With An Improved Heliocentric Model (The AP Theory)

$80.00 Hardcover • $60.00 Softcover

23 original 4-color high gloss prints included.

SATISFACTION GUARANTEED

E-book from Xlibris

THE ONLY COMPREHENSIVE DESCRIPTION OF THE FORMATION OF WATER FROM GAS EVER PUBLISHED.

"The theory of Relativity was disproven when Edwin Hubble Discovered an expanding Universe. Years later it was learned Einstein had "fudged" his equation by introducing the now discredited "cosmological constant" to prove a contracting universe. In light of his confession, educators and the Astronomy community were in danger of "losing control of the game" so the establishment embraced "The Nebula Hypothesis". After spending large amounts of resources and man power they soon found accretion was deeply flawed even after bending some of the rules of physics it was found, accretion could not be proven. Many Astronomers are now walking away from that train of thought and leaning in a new direction of planetary and water formation. The thermal reaction process "The formation of water and our solar system from a fission process with an improved heliocentric model The AP Theory" describes in detail how our solar system formed from the consequences of freezing and thawing of galactic gases and kinetic energy. This internationally acclaimed book with it's controversial "bold truth" descriptions of the formation of our solar system, is sweeping through the Astronomy community like a fresh "growing spring rain" and is being embraced by many scientists and non scientists alike. Grounded in science; it dispels many myths and misconceptions by offering a definitive description and chronological interpretation of how water and our solar system formed. The AP Theory is an easy to read, one of a kind, essential book and a welcome literary addition. It chronologically describes exactly how and when Hydrogen and Oxygen became water and where the heat and pressure came from to forge the gases into H2O. The author offers compelling evidence to prove gravity in not holding down our atmosphere but rather heliospheric gases of lighter atomic weight are. The AP Theory is a good reference book for the latest astronomy facts and discoveries."

www.aptheory.info • Barnesandnoble.com

Amazon.com • orders@xlibris.com.au

Volume Discounts library & school sales
aptheory@aptheory.info

SkyBT

Bluetooth™ Telescope Controller

ANDROID

Coupon Code BT14 for 10% OFF!

SkyFi

Wireless Telescope Controller

iOS/OSX

Coupon Code Fi14 for 10% OFF!

www.skysafariastronomy.com

Simulation Curriculum

COMPELLING SCIENCE for curious minds.

Newton's apple.
Edison's lightbulb.
Hawking's astrophysics.

Subscribe to *Discover* magazine and see where your curiosity takes you.

10 issues JUST $19.95

Go to DiscoverMagazine.com or call 1-800-829-9132

Available in print or digital format.

P22872

Introducing the NEW iEQ30 Pro™

iOptron

#3000E - Reg. $1448. Now $1299

Hands On Optics
1.866.726.7371
www.handsonoptics.com

High Point Scientific
1.800.266.9590
www.highpointscientific.com

OPT
1.800.483.6287
www.opttelescopes.com

Telescopes.com
1.800.303.5873
www.telescopes.com

Woodland Hills Telescopes
1.888.427.8766
www.telescopes.Net

Ontario Telescope (Canada)
1.905.487.6363
www.ontariotelescope.com

www.iOptron.com

FAST FACT

The black holes in merging galaxies will form a binary pair at the center of the new galaxy before ultimately merging themselves.

COURTESY MICHAEL KOSS

ASTRO**CONFIDENTIAL**

BY KARRI FERRON

WHAT ARE WE LEARNING ABOUT BLACK HOLES IN MERGING GALAXIES?

Michael Koss
Ambizione Fellow at the ETH Zurich Institute for Astronomy in Switzerland

At the hearts of large galaxies lie supermassive black holes. Some radiate billions of times as much energy as our star. We refer to galaxy centers exhibiting such intense emission as active galactic nuclei (AGNs). Many scientists think disruptive events like galaxy collisions trigger active galaxies to switch on by sending large amounts of gas toward the black holes; however, capturing this triggering mechanism has proved difficult.

Until the Swift space telescope's hard X-ray survey, astronomers never could be sure they had counted the majority of AGNs. Thick clouds of dust and gas surround the black hole in an active galaxy, which can block other radiation wavelengths. Hard X-rays can help scientists directly detect the energetic black hole even in a galaxy merger.

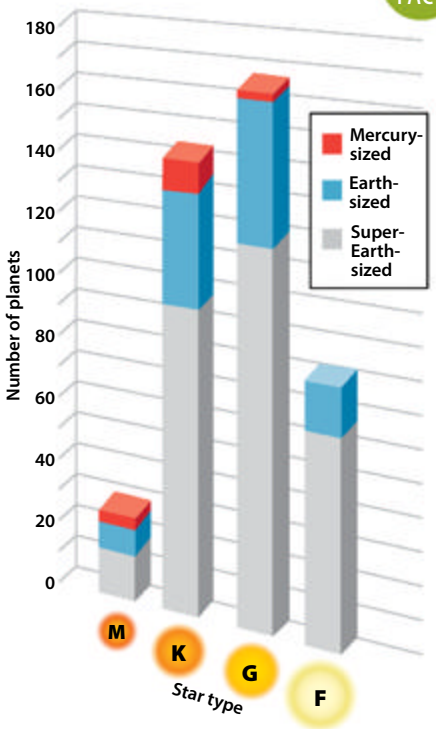
If two galaxies collide and each possesses a supermassive black hole, there should be times when both black holes are active. After Swift provided a wide-angle view, the Chandra X-ray Observatory resolved details a hundred times smaller and tested whether both galaxies were active in a merger. We found that nearly all gas-rich major mergers identified with Swift and Chandra were dual active galaxies, suggesting the merger played an important role in activating the black holes.

Another exciting area astronomers study in galaxy mergers is recoiling black holes. Merging black holes release a large amount of energy in the form of gravitational radiation, a consequence of Einstein's theory of gravity. Waves in the fabric of space-time ripple outward in all directions from accelerating masses. When the black holes merge, lopsided gravitational-wave emission can launch the merged black hole out of the newly formed galaxy's center. Less massive galaxies, called dwarf galaxies, have weaker gravitational potentials and are thought to have much stronger kicks. We have recently found such a recoil candidate in a nearby dwarf galaxy.

ASTRO**NEWS**

ASTEROID OCCURRENCE. A NASA study looking at decades of frequent collisions between meteors and Earth's atmosphere found that the impacts are distributed at random around the globe.

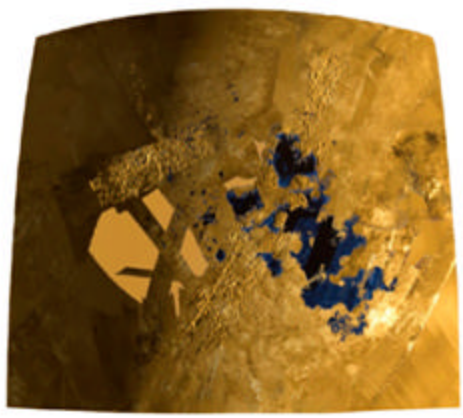
WHERE THE ROCKY WORLDS ARE



FAST FACT

Kepler-37b is the smallest exoplanet found to date, with a diameter only slighter larger than that of the Moon. It orbits a Sun-like G-type star.

EARTH FRIENDS. Scientists using Kepler data are slowly finding more and more rocky planets, including those that are 1.25 to 2 times Earth's diameter (super-Earth-sized worlds), those that are Earth-sized, and those that are even less than 75 percent of our planet's diameter. And astronomers aren't just finding these exoplanets around Sun-like type G stars. This graph shows the numbers of exoplanets with known diameters around each stellar type as of November 31, 2014. *ASTRONOMY*: KARRI FERRON AND ROEN KELLY



BRINY DEEP. Saturn's moon Titan is the only other world in our solar system with liquid lakes. Thanks to NASA's Cassini mission, astronomers are getting a good look at Kraken Mare, the largest of two seas on the moon, and believe the hydrocarbon liquids could reach depths of more than 650 feet (200 meters). NASA/JPL-CALTECH/ASI/USGS

Cassini finds depths of Titan's lakes

Scientists using NASA's Cassini spacecraft measured the depths of lakes on Saturn's moon Titan, finding the shallow end of Kraken Mare is perhaps more than 100 feet (30 meters) deep. But the spacecraft's radar instrument couldn't probe the depths of the central region, implying the lake bottom there is more than 650 feet (200m) deep or the liquid is too absorbing. More tests are planned to pin down Kraken Mare's absorptivity.

A previous study showed nearby Ligeia Mare to be 560 feet (170m) deep in at least one location, which is greater than Lake Michigan's average depth. The results were presented at the Division for Planetary Sciences meeting in Tucson in November.

Past research also has shown that 97 percent of Titan's lakes sit in an area roughly the length of the West Coast and twice the width of California. Scientists suspect the region was created when fissures deformed the moon's crust, allowing it to fill with liquid. — **E. B.**

ASTRONEWS

LUNAR MISSION ONE

MOON SHOT. Lunar Mission One hopes to raise hundreds of millions of dollars for a robotic drilling mission.

Crowdfunded space missions take off

Research funding has taken a hit in recent years as governments grapple with tighter budgets. And in response, scientists have turned increasingly (with mixed results) to private dollars for help making up the shortfalls. Those efforts reached a crescendo in November when Lunar Mission One announced its intention to go to the Moon with a Kickstarter campaign and reached their initial goal by year's end. The group, which includes scientists from the Rosetta mission, wants to send a lander to the lunar pole and drill dozens of feet below the surface, revealing 4.5-billion-year-old clues to the Moon's formation.

The Sentinel Mission, led by Apollo 9 astronaut Rusty Schweickart and other prominent scientists and astronauts, is also chasing private support. That team hopes to place an infrared space telescope in orbit to hunt for near-Earth asteroids. A separate companion effort, Asteroid Day, was also launched in early December with a celebration planned for June 30, 2015, the 107th anniversary of the Tunguska event. Supporters hope to raise awareness for a 100-fold increase in asteroid detection abilities that might someday protect Earth from incoming space rocks. — **E. B.**

25 years ago in *Astronomy*

Astrophysicist John Bahcall covered the solar neutrino problem in March 1990. Along with Ray Davis Jr. (2002 Nobel Prize), he found the Sun made fewer neutrinos than expected. The find tested theories of how stars make energy and led to proof that neutrinos change form en route to Earth, veiling their presence.

10 years ago in *Astronomy*

For the March 2005 issue, then *Astronomy* Associate Editor Francis Reddy interviewed Father George Coyne, the Vatican's former chief astronomer, discussing faith, science, and big telescopes. Rather than being at odds, the priest said he believes science and religion complement each other. — **E. B.**

A DECADE OF SWIFT. NASA's Swift X-ray telescope celebrated a decade of discovery November 20. The highly successful scope finds some 100 stellar explosions a year and can turn its eye with unique speed to watch celestial events unfold.

FIRED UP. Scientists have spent years upgrading the Large Hadron Collider to handle energies never before seen by an atom smasher. CERN

LHC to hunt dark matter

The largest scientific experiment on Earth is ramping back up this year. The Large Hadron Collider (LHC) shut down for maintenance and upgrades in 2013 after detecting the Higgs boson, a long-sought particle responsible for giving mass.

Beam tests begin again in February, as the European Organization for Nuclear Research (CERN) prepares for energies up to 13 trillion electron volts this time — nearly double what was seen in the previous run and substantially higher than ever before achieved.

CERN officials say this new hunt will look for evidence of dark matter in hopes of better understanding the composition and history of our universe. **— E. B.**

Did gravity save the universe?

The standard model of particle physics, making use of the newly discovered Higgs particle — responsible for giving particles mass — suggests the universe should have collapsed on itself following the Big Bang. Some propose that new physics is needed to explain why this didn't happen.

However, a theory published November 17 in the journal *Physical Review Letters* suggests a simple salvation. The authors show that even a small interaction between the Higgs and gravity would have been enough to stabilize the universe. The European team hopes to measure this interaction, which they say is the last unknown number of the standard model, using observations of the cosmic microwave background. **— E. B.**

T. ARAI/UNIVERSITY OF TOKYO

LIGHTING THE VOID. Physicists say the space between galaxies glows with light from galaxy-less stars.

Rocket experiment explains cosmic glow

A sea of unseen stars lights the voids of our universe, giving a steady glow to regions between galaxies long believed to be dark. That's the conclusion of the Jet Propulsion Laboratory (JPL) scientists behind NASA's Cosmic Infrared Background Experiment rockets launched between 2009 and 2013 to help settle a long-standing debate about the glow's origin.

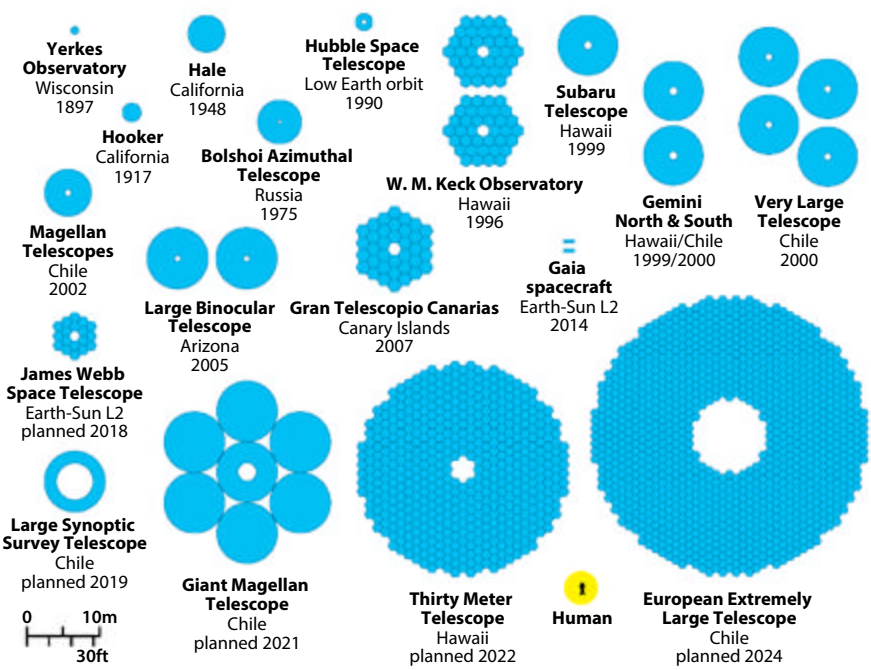
For decades, astronomers have speculated about the cosmic infrared background — a strange, splotchy light stronger than the collective brightness of all galaxies. However, recent infrared satellite observations have helped fuel discussion about whether this immense cosmic light pollution was coming from the first galaxies to form and spark stars after the Big Bang, or if it stemmed from ejected stars adrift between galaxies.

The JPL team originally suspected the light was coming from early galaxies, but the data they captured in repeated wide-field imaging above the atmosphere changed their minds. In a paper published November 7 in *Science*, the authors, including a large international team, say the light they discovered is too bright and too blue, implying a more recent formation. More experiments are planned to refine the results. **— E. B.**

THE NEXT GENERATION OF TELESCOPES

FAST FACT

The three smallest ground-based scopes shown were the world's best for nearly a century.



OPTICAL EVOLUTION. The telescopes of a century ago will look like toys in comparison to the colossal observatories now being built. Mount Wilson's famous Hooker Telescope reigned as the world's largest from 1917 to 1948, when the Hale Telescope was finished. At 100 inches (2.5 meters) across, the Hooker's primary mirror was a modern marvel at the time, but when the Thirty Meter Telescope is complete around 2022, its mirror will stretch a truly mind-boggling 100 feet from edge to edge. *ASTRONOMY:* ROEN KELLY AND ERIC BETZ, AFTER CMGLEE/WIKIMEDIA COMMONS

$1.267 billion

The estimated cost to complete the European Extremely Large Telescope in Chile and its 39-meter (128 feet) primary mirror, now in the first phase of construction.

ESA/HUBBLE (M. KORNMESSER) (HUBBLE); NASA/ESA/STSCI/JEFF HESTER AND PAUL SCOWEN (ARIZONA STATE UNIVERSITY) (PILLARS)

FOCUS ON:
MODINE-BENSTEAD OBSERVATORY
UNION GROVE, WISCONSIN

The Racine Astronomical Society was established in 1956 to promote interest in astronomy among amateurs and the Racine area public. The Modine-Benstead Observatory was completed in 1963 and includes two observatories with Ash Domes. The main building includes a 16-inch Cassegrain telescope, an observation deck, library and meeting room. The second houses our 14-inch Celestron telescope.
www.rasastro.org

ASH MANUFACTURING COMPANY
P.O. Box 312 • Plainfield, IL USA 60544
815.436.9403 • FAX 815.436.1032
web site: www.ashdome.com • email: ashdome@ameritech.net

ASH-DOME is recognized internationally by major astronomical groups, amateurs, universities, colleges secondary & primary schools for their performance durability and dependability. Manual or electrically operated units in sizes from 8 to 30 feet in diameter; sensibly priced. Brochures and specifications available.

Telescopes.net

APOGEE IMAGING • ASA • ATIK • CANON • CELESTRON • CORONADO • EXPLORE SCIENTIFIC • FARPOINT • FLI • JMI • KENDRICK • LUMENERA • LUMICON • MEADE • MOONLITE

OFFICINA STELLARE ORION • QSI • SBIG • SKY-WATCHER USA • SOFTWARE BISQUE • STARLIGHT EXPRESS • TAKAHASHI • TELE VUE • THE IMAGING SOURCE • VIXEN PLANEWAVE

Introducing MallinCam cameras

ED80mm by Explore Scientific

Astro-Optic

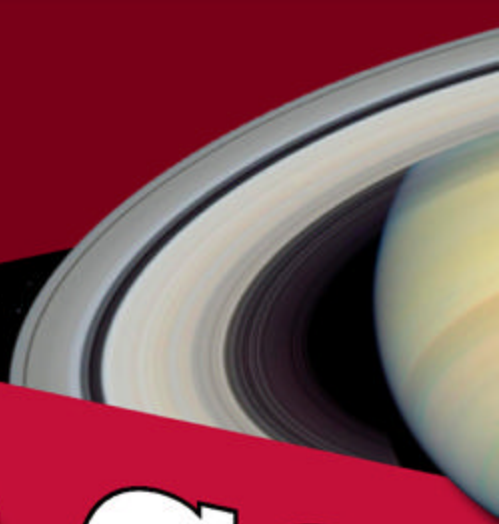
The best Finder/220mm Guider you can buy for $89.00

CELESTRON

CGE Pro 1400 HD

Woodland Hills Telescopes
5348 Topanga Canyon Blvd.
Woodland Hills, CA 91364
Mon-Sat: 9am-6pm (PST)
Toll Free: (888) 427-8766
Local: (818) 347-2270
Fax: (818) 992-4486

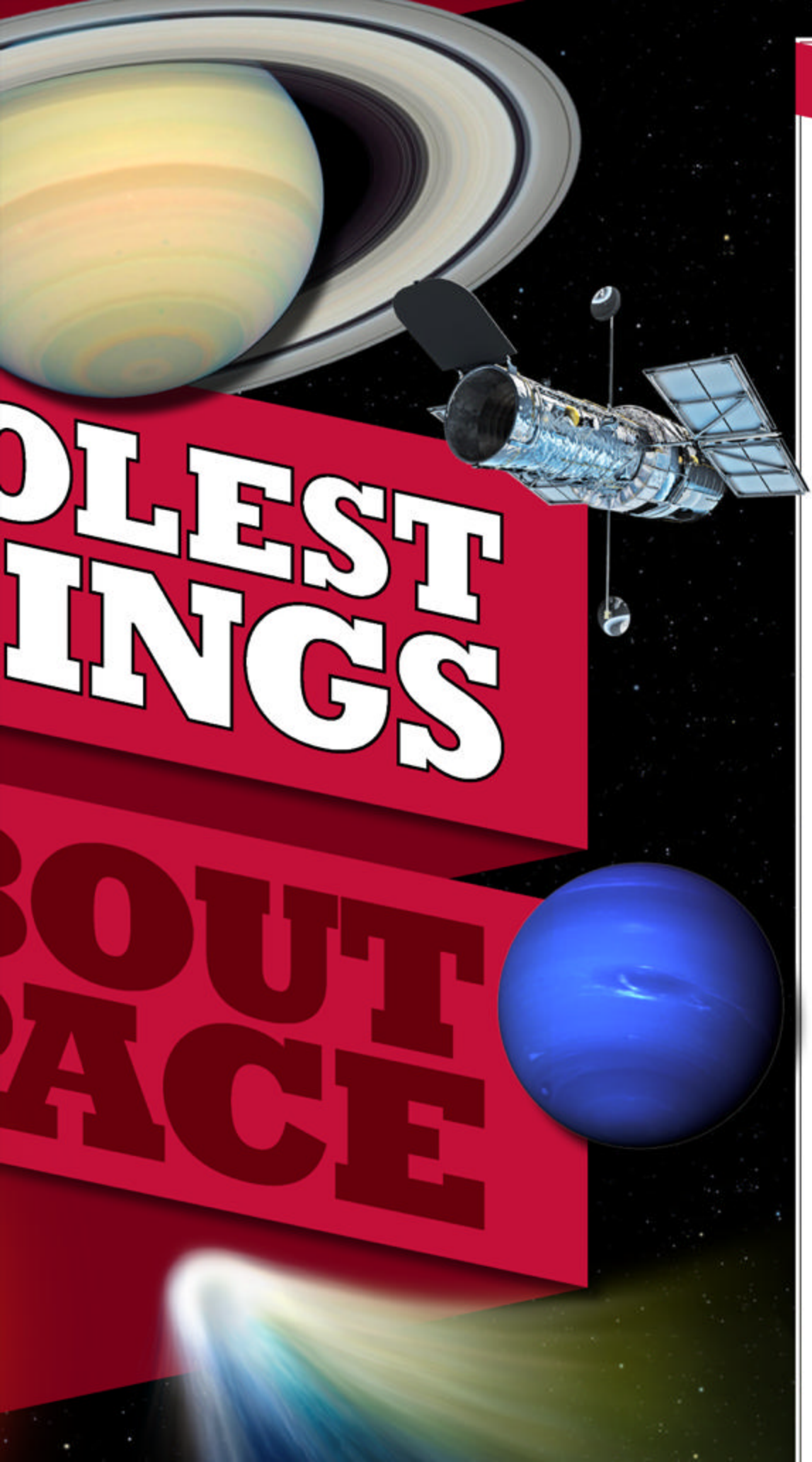
THE 500 COOLEST THINGS ABOUT SPACE



WE ALL KNOW ASTRONOMY IS COOL. But have you ever sat under the stars and had a conversation about the most fascinating things in our beloved science? The editors of *Astronomy* have. And we thought it a big enough topic to bring to our readers. But instead of printing a "Top 10" or even a "Top 100" (both popular formats), we waited for our 500th issue so that we could devote it to the 500 coolest things about space.

You'll find topics on every aspect of the cosmos (in no particular order), from the incredibly small (the Higgs boson) to the impossibly large (the expanding universe). We've listed lots of "firsts," the most epic discoveries, and the best technological achievements. You'll find facts about stars, planets, constellations, galaxies, and even the stuff we can't see. Did you know that English astronomer William Herschel, who found the seventh planet, Uranus, also discovered infrared radiation?

We really enjoyed putting this list together, and we're sure you're going to have fun with it. We think many of you also will have a blast sharing some of the little-known tidbits with your friends the next time you're under the stars.



THE LIST

OLEST INGS BOUT PACE

1 Exactly 88 constellations cover the sky with no gaps and no overlaps.

2 The solar system's largest moon, Ganymede, contains 25 percent more volume than Mercury.

3 At a distance of 4.2 light-years, Proxima Centauri (Alpha Centauri C) is the closest star to the Sun.

4 Of the 9,113 official features on the Moon, a mere 421 (4.6 percent) are not craters.

5 Two globular clusters vie for the title of nearest to Earth: M4 in Scorpius and NGC 6397 in Ara. Each lies 7,200 light-years away.

6 Every 27 years, a dark disk of dust eclipses the primary star in the double star system Epsilon Aurigae, cutting its light output by 50 percent for hundreds of days.

7 In 2014, scientists studying the jovian moon Europa discovered evidence of plate tectonics, a first for a world beyond Earth.

8 Saturn's moon Enceladus likely has a large subsurface sea that feeds the geysers shooting from its south polar region.

9 The solar antapex, the point away from which the solar system is moving, lies in the constellation Columba the Dove at right ascension 6 hours and declination –34°.

10 The most luminous star visible to the naked eye, 34 Cygni, outshines the Sun by 610,000 times.

11 The Lunar Crater Observation and Sensing Satellite found water ice in Cabeus Crater on the Moon in 2009.

12 Mercury is the only planet on which scientists have never witnessed an auroral display.

ASTRONOMY: ROEN KELLY (SUN, COMET, STAR FIELD); NASA/ESA/ERICH KARKOSCHKA (UNIVERSITY OF ARIZONA) (SATURN); ESA/HUBBLE (M. KORNMESSER) (HUBBLE); NASA (NEPTUNE)

13 If Earth were the size of a tennis ball, the Sun would be a sphere 24 feet across approximately 0.5 mile away.

14 The Coalsack is a dark nebula visible to the naked eye in the southern constellation Crux that covers 30 square degrees of sky area.

15 Chemistry professor John William Draper recorded the Moon on the first astrophoto on March 23, 1840.

16 French scientist Jean-Baptiste Biot studied the April 26, 1803, L'Aigle meteorite fall and confirmed that the rocks came from space.

17 The terms "Tropic of Cancer" and "Tropic of Capricorn" originated several thousand years ago when the Sun stood before the stars of those constellations on the summer and winter solstices, respectively.

27 TINY TRAVELER

In 1957, a beach-ball-sized metal sphere called Sputnik became the first satellite to enter Earth orbit, broadcasting its Soviet radio pulses and ushering in the Space Race.

18 On October 19, 2014, Comet Siding Spring (C/2013 A1) passed within 87,000 miles of Mars — one-third of the distance between Earth and the Moon.

19 In 1972, Cygnus X-1 became the first X-ray source widely recognized to be a black hole.

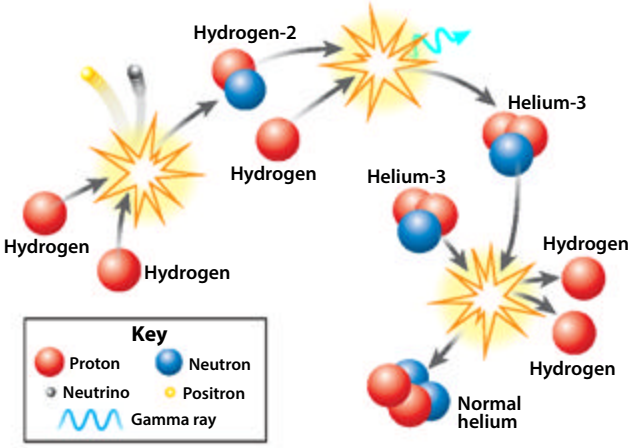
28 DOWN THE RABBIT HOLE

Everyone associates the idea of black holes with Albert Einstein and his general theory of relativity. The great scientist published this landmark theory in 1915, and within a year, German physicist Karl Schwarzschild had worked out the equations to describe an object from which light cannot escape.

But the idea of black holes stretches back more than a century before Einstein. In 1783, British professor John Michell advanced the idea that a massive star could grow large enough that its gravitational pull would prevent light from escaping. Then, in 1795, French astronomer and mathematician Pierre-Simon Laplace independently developed the same hypothesis and dubbed the objects "dark bodies." Working in the 18th century, both scientists hammered out the physics using Isaac Newton's concepts of light and gravity.

Unfortunately, Newton's theory could not describe what happens when gravity grows this strong, and the idea quietly died. It didn't come back until Schwarzschild worked his mathematical magic, but even then, most scientists didn't believe such objects could exist. Today, however, astronomers see evidence of them everywhere. In binary systems, a black hole can siphon gas from its companion star, creating a disk of hot gas that glows brightly in X-rays (the illustration shows a famous example, Cygnus X-1). And supermassive black holes lurk at the centers of most large galaxies, where they can drive the outbursts seen in quasars and other active galaxies.

29 LET THE SUN SHINE



In the early 1920s, British astronomer Arthur Eddington showed that a fine balance exists in stellar interiors between the inward pull of gravity and the outward push of heat and radiation pressure. And to counteract the great mass in a star's overlying layers, its core must be blisteringly hot. Combined with the stellar abundances of hydrogen and helium, this led him to propose that stars shine by fusing hydrogen into helium. Although it took until the 1930s for physicists to work out how fusion operated (the proton-proton cycle shown here dominates in low-mass stars like the Sun), Eddington's insights paved the way.

20 The common names of the stars Alpha and Beta Delphini, Sualocin and Rotanev, respectively, spelled backward give the Latinized name of Niccolò Cacciatore — Nicolaus Venator — the assistant of Italian astronomer Giuseppe Piazzi.

21 Astronomers have studied nearly 500 comets orbiting the star Beta Pictoris and discovered that they belong to two distinct families of exocomets.

22 If you drilled a tunnel through Earth and jumped in, you would reach the other side in 42 minutes and 12 seconds, and your top speed would be 17,670 mph.

23 By total energy, sunlight is some 50 percent infrared light, 40 percent visible light, and 10 percent ultraviolet light.

24 The biggest supermassive black hole found to date, weighing in at some 21 billion solar masses, resides in the elliptical galaxy NGC 4889.

25 The five most common elements in the Sun by mass are hydrogen (73.90 percent), helium (24.69 percent), oxygen (0.63 percent), carbon (0.22 percent), and neon (0.17 percent).

26 In 1983, scientists verified that a group of 14 meteorites came from Mars.

NASA (TRAVELER); NASA/CXC/M. WEISS (RABBIT); *ASTRONOMY*: ROEN KELLY (SUN SHINE)

30

INTO THE DEEP

Telescopes are time machines. By looking at the most distant objects their optics allow, these instruments can peer back in time to when the light left those targets. So when the Hubble Space Telescope returned its first clear images of distant galaxies after its 1993 servicing mission, Robert Williams, then director of the Space Telescope Science Institute, was inspired to use the instrument to "go deep" back in time. For 10 consecutive days in December 1995, Hubble stared at a tiny, relatively nondescript patch of sky near the handle of Ursa Major's Big Dipper, collecting 342 separate exposures with its main camera. What the data revealed was astonishing: more than 3,000 galaxies in a variety of shapes and sizes, most seen for the first time as they glow 4 billion times fainter than what's visible to the naked eye.

This Hubble Deep Field shows some galaxies as they were more than 10 billion years ago, allowing scientists to study galaxy formation and evolution, the universe's large-scale structure, and even the fate of the cosmos. Since this historic campaign, Hubble has followed up with similar deep fields using newer optics, including 2012's eXtreme Deep Field, which showed galaxies as they were some 13.2 billion years ago. But no image beats the first truly deep look back in time to our infant universe.

R. WILLIAMS (STSCI)/THE HUBBLE DEEP FIELD TEAM/NASA

31

EXOPLANET EXTRAVAGANZA

When Bill Borucki first considered a workhorse mission to find worlds around other stars by studying dips in their light when a would-be planet passed in front of one such sun, exoplanets were still just a theory. It took years of rejection before his concept, which would become the Kepler space telescope, launched March 6, 2009, to study some 150,000 stars in the constellations Cygnus and Lyra; on that date, there were 374 known exoplanets, discovered over the course of 17 years. But with this new spacecraft, discoveries soared, the exoplanet zoo became much more varied, and data even revealed that there could be as many as 40 billion Earth-sized planets orbiting at the right distances from their stars to host liquid surface water. Despite losing its second of four critical reaction wheels in May 2013, the Kepler mission lives on as scientists continue to sift through data, following up on planet candidates. As of December 15, 2014, the space telescope had bagged 996 confirmed exoplanets and found another 4,183 planet candidates. A true workhorse indeed.

LYNETTE COOK, FOR *ASTRONOMY* (EXOPLANETS); NASA (KEPLER)

32 MARTIAN MAPS

Giovanni Schiaparelli's late-19th-century map of Mars caused an uproar when he identified thin lines across the surface as *canali*. In Italian, this means grooves or channels, but English speakers translated the term as man-made canals.

34 The Mariner 4 spacecraft performed the first successful flyby of Mars on July 14, 1965.

35 Researchers detected the first interstellar molecule, the methylidyne radical (CH), in 1937.

36 When Mars appears opposite our Sun in the sky, the Red Planet can lie as close as 35 million miles to Earth or as far as 60 million miles away.

37 The Boomerang Nebula in the constellation Centaurus is the coldest natural place in the universe, with a temperature 1 kelvin above absolute zero.

38 The largest crater in the solar system, Mars' North Polar Basin, covers 40 percent of the Red Planet.

39 In 1848, Édouard Roche calculated the distance within which a celestial object will disintegrate due to tidal forces from the body it orbits.

40 The 1st-magnitude star Altair (Alpha Aquilae) rotates at a speed of 178 miles per second.

41 A Thorne-Żytkow object is a red supergiant that has swallowed a neutron star, which now lies at its core producing energy.

42 According to NASA, the odds are some 250,000 to 1 that a falling meteorite will be the cause of your death.

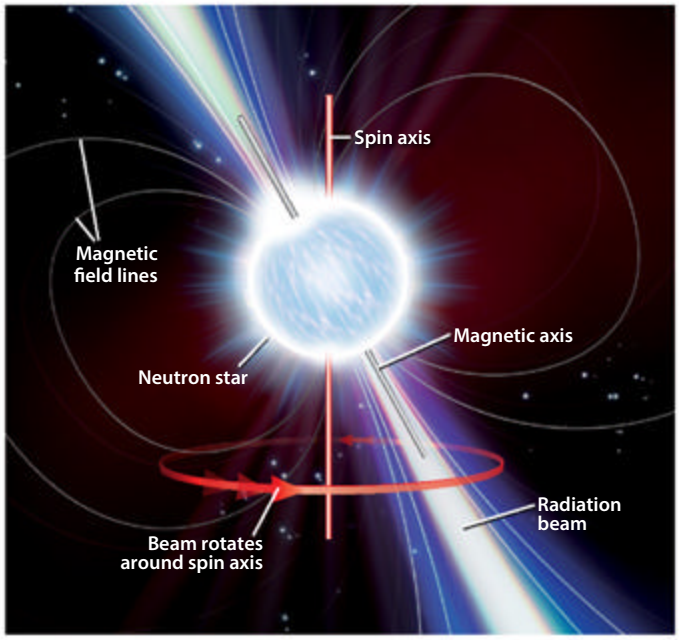
43 In 1655, Dutch astronomer Christiaan Huygens became the first to determine that Saturn has multiple rings.

44 As your eyes adapt to the darkness, their sensitivity increases 10,000-fold in the first 30 minutes, with little gain after that.

45 As of March 20, 2014, approximately 92 million people visit the world's 3,900 planetaria each year.

46 The first solar flare ever observed, on September 1, 1859, by British astronomer Richard Carrington, was also the most powerful.

33 TUNING IN



In 1967, while cataloging "twinkling" radio sources, Antony Hewish and his graduate student Jocelyn Bell stumbled upon a strange signal — radio pulses every 1.33 seconds from a fixed location in the sky. At first, they honestly thought it could be aliens. Follow-up studies quickly revealed something non-extraterrestrial but equally interesting: a pulsar, now known to be a rapidly rotating neutron star. Such objects produce beams of radiation from their magnetic poles, which are misaligned to their spin axes. As a result, the radiation appears to "pulse" in our direction as the stars rotate.

47 A HOLE IN ONE

Opportunity landed January 25, 2004, on the opposite side of Mars from the rover's twin, Spirit, and immediately earned its name. Like its sibling, the rover was sent to find clues to past water on the Red Planet. And find it Opportunity did. The rover's touchdown bounced it right into Eagle Crater, where an impact had serendipitously uncovered ancient evidence of Mars' changing climate. Within months, NASA scientists announced Opportunity had found signs of ancient water flows, implying Meridiani Planum once sat on the shores of a saltwater sea. Stranger still, Opportunity found small spheres dubbed "blueberries" that could have formed from asteroids, volcanic activity, or even flowing water. In 2014, the decade-old Opportunity surpassed 25 miles and became the most traveled vehicle on another world, passing the prior record holder, Russian lunar rover Lunokhod 2. Engineers at NASA's Jet Propulsion Laboratory have since steered Opportunity along the rim of Endeavour Crater, where aside from a number of "amnesia events," the rover is in good health.

LINDA HALL LIBRARY OF SCIENCE, ENGINEERING & TECHNOLOGY (MAPS); *ASTRONOMY*: ROEN KELLY (TUNING); NASA/JPL-CALTECH (HOLE)

48 HALLEY'S HEYDAY

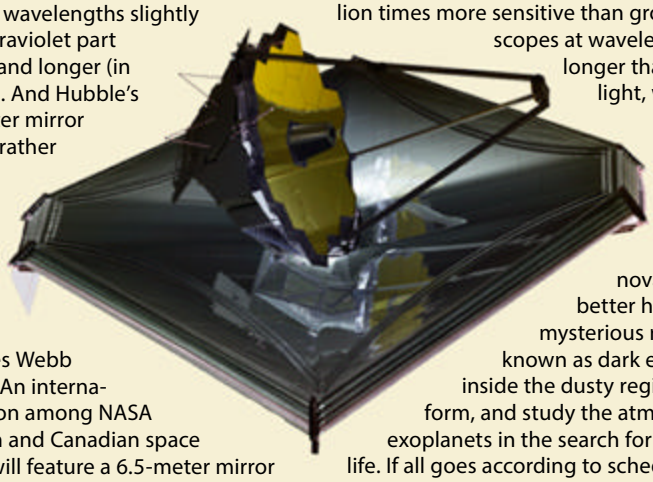
On March 13, 1986, the European Space Agency's Giotto spacecraft flew past Comet 1P/Halley, returning humanity's first close-up images of a comet.

49 REPLACING A LEGEND

The Hubble Space Telescope has delivered a huge number of scientific breakthroughs and incredible images in the 25 years since shuttle astronauts deployed it in April 1990. Yet the iconic observatory can do only so much. Engineers optimized its optics to record radiation over a narrow range centered on visible light and extending to wavelengths slightly shorter (in the ultraviolet part of the spectrum) and longer (in the near-infrared). And Hubble's 2.4-meter-diameter mirror gathers light at a rather pedestrian pace compared with the 8-meter and larger telescopes at many major ground-based observatories.

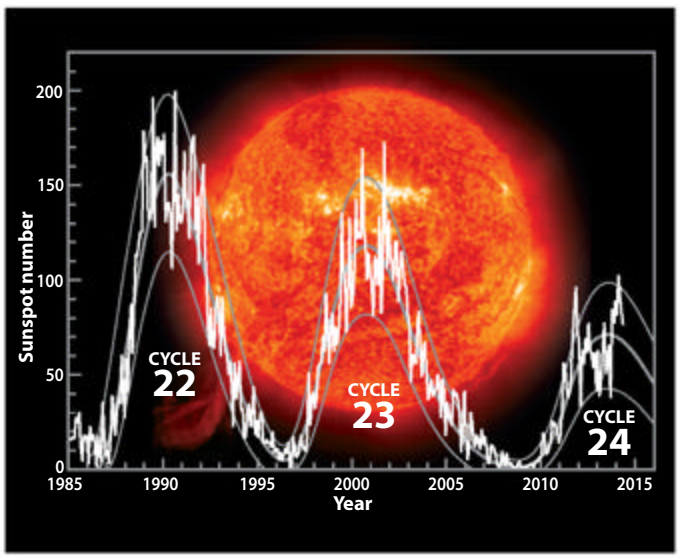
Enter the James Webb Space Telescope. An international collaboration among NASA and the European and Canadian space agencies, Webb will feature a 6.5-meter mirror composed of 18 hexagonal segments. The large mirror has about seven times the collecting area of Hubble's, which means it will record light from objects seven times faster than its predecessor.

But even more significantly, Webb will operate at near- and mid-infrared wavelengths. Why infrared? The expansion of the universe stretches light from the youngest and most distant galaxies from the ultraviolet and visible parts of the spectrum into the infrared. Although Hubble has provided tantalizing views of these objects, Webb will be able to study them in detail. And the newer space telescope will be roughly a million times more sensitive than ground-based scopes at wavelengths 10 times longer than visible light, where Earth's atmosphere becomes largely opaque.



Webb also will observe distant supernovae to get a better handle on the mysterious repulsive force known as dark energy, peer inside the dusty regions where stars form, and study the atmospheres of exoplanets in the search for signs of alien life. If all goes according to schedule, Webb will lift off from French Guiana in 2018 on a trip to the second Lagrangian point of the Earth-Sun system, some 940,000 miles from Earth in the direction opposite the Sun. Once it cools to the temperature of interplanetary space, the discoveries will begin.

50 A SPOTTY RECORD



German astronomer Samuel Heinrich Schwabe discovered the sunspot cycle in 1843 after he had collected 17 years of solar observations. Swiss astronomer Johann Rudolf Wolf used many other observations to determine sunspot numbers back to the early 17th century. Although astronomers refer to this cycle as spanning 11 years, the average is 10.66 years, with some as short as nine and others as long as 14 years. This chart shows sunspot predictions (the smooth curves) and the actual numbers of spots seen.

51 Lying 153 light-years away, the Hyades in the constellation Taurus is the nearest star cluster to Earth.

52 Edward Emerson Barnard made the last visual discovery of a planetary satellite (Jupiter's Amalthea) on September 9, 1892.

53 In 1970, Celestron introduced the first commercially available Schmidt-Cassegrain telescope, the C8.

54 First Quarter Moon and Last Quarter Moon are only 10 percent as bright as the Full Moon.

55 Nova Aquilae 1918, which peaked at magnitude –0.5, was the brightest nova since the invention of the telescope.

56 On July 14, 2015, the New Horizons spacecraft will fly by Pluto after a voyage of 3,463 days.

57 Frisian astronomer Johannes Holwarda discovered the first variable star, Mira (Omicron Ceti), in 1638.

58 In 1783, British astronomer John Goodricke determined that Algol (Beta Persei) is an eclipsing binary.

59 The Sun contains 99.86 percent of all the mass in our solar system.

60 During its appearance in 1996 and 1997, Comet Hale-Bopp (C/1995 O1) became the most observed comet ever, remaining above naked-eye visibility for an incredible 18 months.

61 Two septuple star systems are known to exist: Nu Scorpii and AR Cassiopeiae.

62 The International Astronomical Union formalized the constellation boundaries in 1928.

ESA (HALLEY); NORTHROP GRUMMAN (LEGEND); *ASTRONOMY*: ROEN KELLY, AFTER HATHAWAY/NASA/MSFC (RECORD)

The last supernova visible from Earth with naked eyes was Supernova 1987A, the "spiky" star to the right of center in this image. The blast lit up the Large Magellanic Cloud in early 1987.

63

BLAST OFF

On February 23, 1987, events started to unfold that would both radically change and reassuringly confirm astronomers' expectations of how massive stars explode. That night, Supernova 1987A first appeared in Earth's sky. Located in the Large Magellanic Cloud, a satellite galaxy of the Milky Way, it gave observers a ringside seat to star death. Over the ensuing weeks, it would become the brightest supernova in nearly 400 years.

SN 1987A peaked at magnitude 2.9 in May, well below a predicted 1st-magnitude maximum. The reason: The star that exploded, cataloged as Sanduleak –69°202, was a hot blue supergiant and not the cool red supergiant everyone expected. The denser blue supergiant sapped some of the energy from the shock wave that ripped the star apart.

But another aspect of supernova theory received hearty confirmation from SN 1987A. Theorists had surmised that as a massive star's core collapses (the trigger for the explosion), it should generate a flood of neutrinos. These nearly massless subatomic particles rarely interact with matter and should escape immediately. When neutrino detectors in Ohio, Japan, and the Soviet Union captured about two dozen of these particles, they confirmed the general scenario.

Material released by Supernova 1987A's progenitor star tens of thousands of years ago lights up as the explosion's shock wave slams into it. The supernova remnant itself appears as a pinkish glow inside the ring.

ESO (WIDE FIELD IMAGER); NASA/ESA/R. CHALLIS AND P. KIRSHNER (HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS) (CLOSE-UP IMAGE)

The path of the total solar eclipse that will sweep across the United States on August 21, 2017, begins in Oregon and ends in South Carolina. The spectacular eclipse sequence at left occurred above the Ob Reservoir in Novosibirsk, Russia, on August 1, 2008.

64

LOOKING FORWARD TO 2017

The first total solar eclipse visible from the continental United States in 38 years occurs August 21, 2017. This event, when the Moon completely covers the Sun's disk from Earth's perspective, is likely to be the most viewed eclipse ever, so the time to start planning where you will be on that date is now.

Great weather should abound along most of the path of totality. The Moon's shadow first touches land in northwestern Oregon, crosses nine more states, and ends its land-locked run in central-east South Carolina before heading into the Atlantic Ocean.

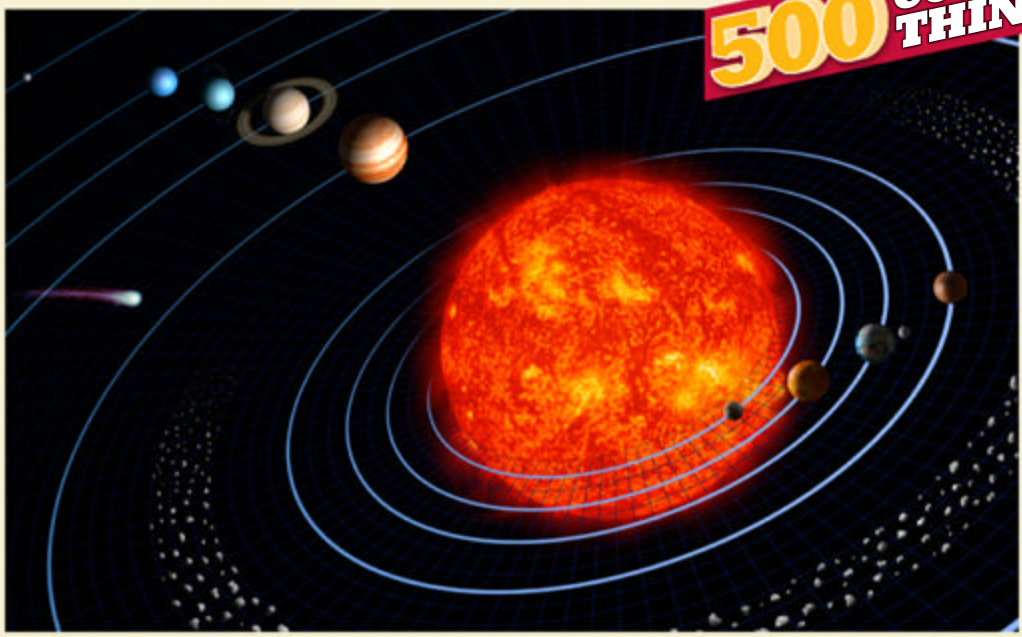
Nashville is the only large city the center line (the part of the path of the Moon's shadow that offers the longest duration of totality) passes through. Many others, including Portland, Denver, Kansas City, Saint Louis, Memphis, and Atlanta, sit within easy driving distance of totality. The point of greatest eclipse — which offers 2 minutes, 40 seconds of totality — lies slightly south of Carbondale, Illinois. But many locations feature totalities within a few seconds of maximum.

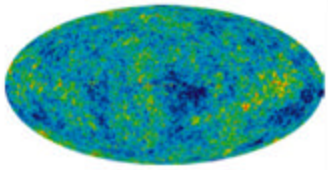
BEN COOPER (ECLIPSE PHOTO); *ASTRONOMY*: ROEN KELLY (ILLUSTRATION)

65 ROUND AND ROUND

The Greek astronomer Aristarchus of Samos (310–230 B.C.) was the first to propose the heliocentric system, effectively taking Earth out of the center of the solar system and replacing it with the Sun.

While the book he wrote that included the theory has not survived the intervening centuries, another Greek mathematician, Archimedes, mentioned Aristarchus' theory in *The Sand Reckoner*. (Interestingly, in *The Sand Reckoner*, the author attempted to calculate the number of grains of sand that would fit inside the universe.)





66 AGE IS JUST A NUMBER

Thanks to the Wilkinson Microwave Anisotropy Probe, which studied the remnant radiation from the Big Bang (the cosmic microwave background, pictured) for nine years, scientists pinned down the age of the universe, announcing it as 13.7 billion years in 2003 and refining it to 13.772±0.059 billion in 2012. Today, combined with more data, the current cosmic age is 13.798±0.037 billion years.

67 The Huygens probe became the first human-made object to land on Saturn's moon Titan on January 14, 2005.

68 Saturn is the only planet with a density less than water.

69 British astronomer Isaac Roberts became the first to record spiral structure in the Andromeda Galaxy (M31) in a photo he took December 29, 1888.

70 American physicist Carl D. Anderson discovered the first antiparticle — the positron — August 2, 1932.

71 The odds are greater than 7-to-1 that on your birthday, the Sun was not in what you think is your zodiacal constellation.

72 Because of its thick atmosphere, Venus' surface fries at 864° F, at least 75° F hotter than Mercury's.

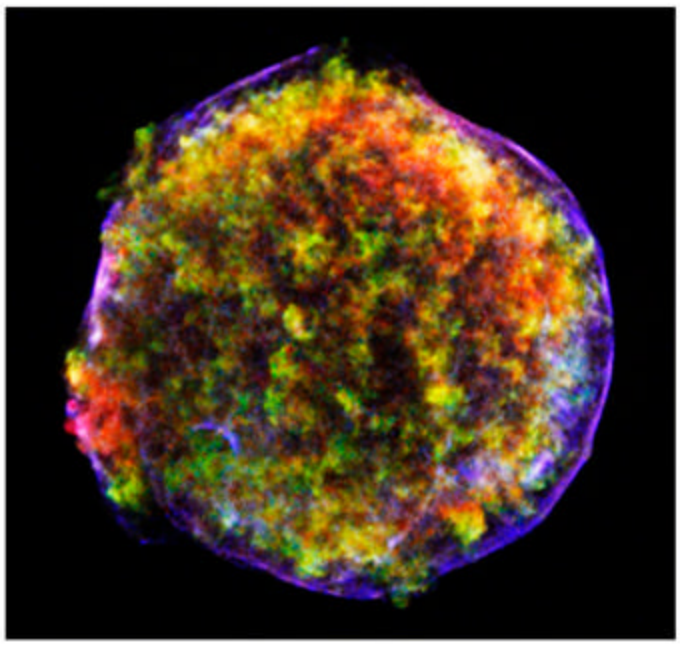
73 The Sun converts 4 million tons of mass into 384.6 septillion watts of energy each second.

74 The biggest constellation ever recorded, Argo Navis, covered 28 percent more area than today's largest recognized constellation, Hydra.

75 ONE TWO-BILLIONTH

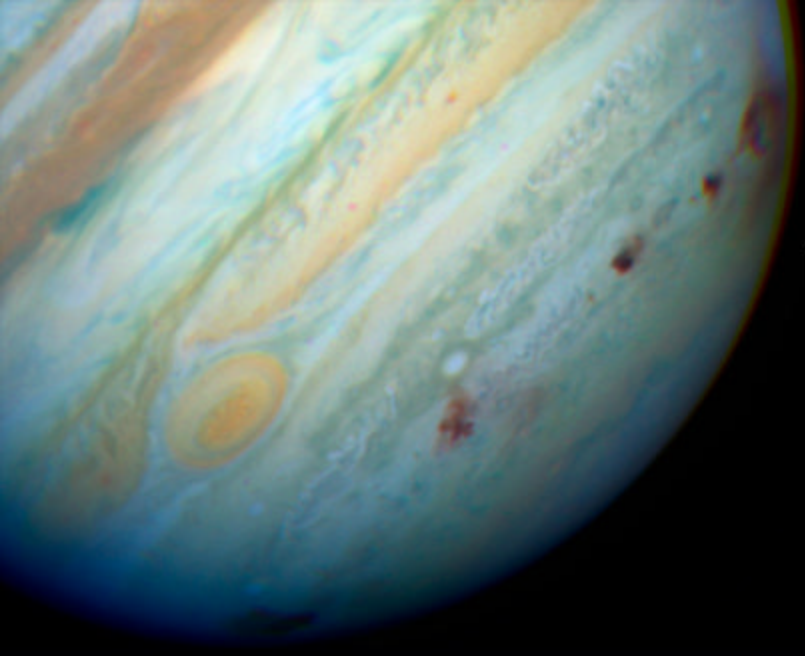
The amount of the Sun's energy that falls on Earth

76 NEW STAR



Historians often call the supernova of 1572 "Tycho's Star" because of *De Nova et Nullius Aevi Memoria Prius Visa Stella* ("On the New and Never Previously Seen Star"), a printed work by Danish astronomer Tycho Brahe. In it, he used the new object to challenge the view that the heavens never change. He also measured the parallax of the bright "star" and showed that it lay far beyond the Moon. Astronomers created this false-color image of the supernova remnant called Tycho's Supernova (SN 1572) using data from the Chandra X-ray Observatory.

NASA/JPL (ROUND); NASA/WMAP SCIENCE TEAM (AGE); NASA/CXC/RUTGERS/J. WARREN AND J. HUGHES, ET AL. (STAR)



Dark scars resulting from multiple impacts of the fragmented comet mar the colorful cloud tops of Jupiter in this July 1994 Hubble image.

NASA/HAL WEAVER AND T. ED SMITH (STScI) (COMET SHOEMAKER-LEVY 9); NASA/HUBBLE SPACE TELESCOPE SCIENCE TEAM (JUPITER IMPACTS)

77

DEATH AT JUPITER

Comets often meet their demise when they pass too close to the Sun. Our star's searing heat and immense gravity literally can tear these icy visitors to bits. But in 1994, a comet met its ultimate fate when it smashed into Jupiter — the only known comet to ever crash into a planet.

American astronomers Eugene and Carolyn Shoemaker, working with renowned observer David Levy, discovered Comet Shoemaker-Levy 9 on March 24, 1993. Researchers soon learned that this comet was not a single object, however, but a couple dozen fragments traveling together through space. Back in July 1992, the comet had passed near Jupiter, and the giant planet's gravity tore it to pieces. Beginning July 16, 1994, and lasting for nearly a week, the individual fragments rained down on Jupiter's cloud tops. The impacts created dark scars that remained visible through amateur telescopes for months.

78 FIRST WORLD SURPRISES

As the search for worlds beyond our solar system heated up in the early 1990s, planet hunters targeted stars similar to the Sun. So, imagine the shock most scientists felt when the first planets turned up around a star totally unlike ours during a research project in which planets didn't even rise to the level of afterthought.

Astronomers Aleksander Wolszczan and Dale Frail were seeking millisecond pulsars when they found PSR B1257+12. This neutron star — an object formed when a massive star explodes and leaves behind a remnant as dense as an atomic nucleus — spins once every 6.22 milliseconds. Radio pulses from such objects repeat with precise regularity, so when the astronomers noticed a pattern of changes to the pulses, they knew something was up. The timing shift indicated gravitational wobbles induced by three orbiting planets — two a few times more massive than Earth and one close to the Moon's size. All orbit closer to the pulsar than Earth does the Sun. The age of exoplanets had opened in the most unlikely of places.

79 The Blaze Star (T Coronae Borealis) is a normally 10th-magnitude recurring nova that astronomers saw burst as bright as 2nd magnitude in 1866.

80 On August 24, 2006, members of the International Astronomical Union voted on a proposal that demoted Pluto to non-planet status.

81 Early people used Stonehenge as an observatory starting around 2300 B.C.

82 The earliest eclipse record is of an annular eclipse in Ireland on November 30, 3340 B.C.

83 The research team of the Mars Global Surveyor reported evidence of water flowing in gullies between 1999 and 2005.

84 Hipparcos, the first satellite launched to collect high-precision positions of celestial objects, operated between 1989 and 1993 and produced three catalogs containing 2,539,913 stars.

85 American astronomer Edward Emerson Barnard created the first catalog of dark nebulae in 1919.

86 The Genesis spacecraft returned a sample of the solar wind to Earth in 2004.

87 The Stardust mission returned dust samples from Comet 81P/Wild in 2006.

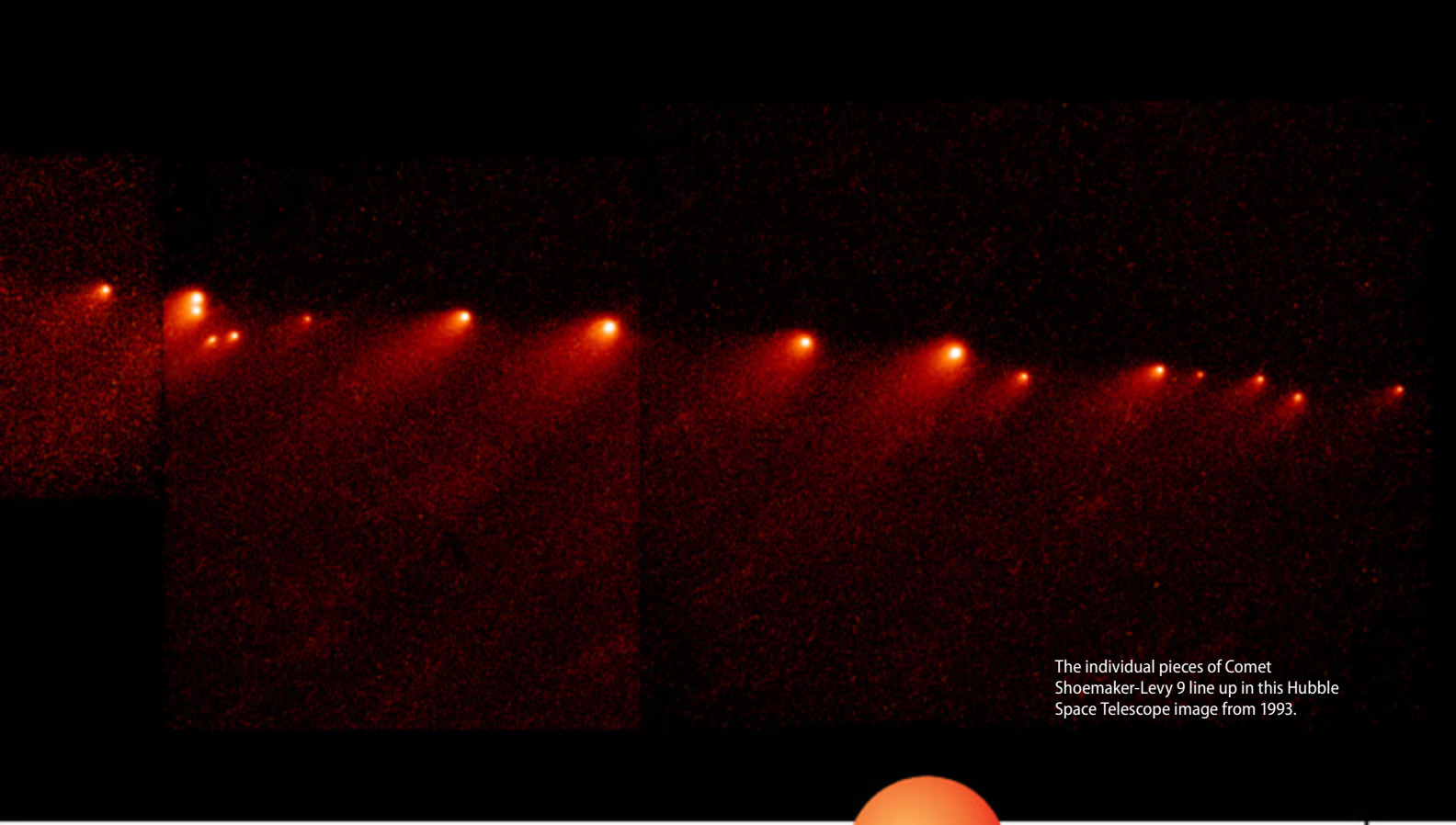
88 The Methuselah Star (HD 140283) is the universe's oldest known star, with an age range right around the beginning of the cosmos.

89 To escape Earth's gravity, a spacecraft must travel more than 25,008 mph, or near Mach 33.

90 The first time astronomers observed a supernova as it occurred was with Supernova 2008D on January 8, 2008.

91 HIGH SOCIETY

Indian theorist Meghnad Saha changed astrophysics in 1920 when he derived an equation to describe ionization in the atmospheres of stars. He was the first astronomer to differentiate spectra this way, but certainly not the last. Understanding stellar classification still depends on his work today.



The individual pieces of Comet Shoemaker-Levy 9 line up in this Hubble Space Telescope image from 1993.

92 Three-quarters of all normal matter in the universe is hydrogen.

93 As of May 14, 2014, 132 of the 59,379 meteorites found so far on Earth came from Mars.

94 Venus has no seasons because of its mild tilt, but multiple impacts pushed Uranus on its side, making for seasons that last 21 years.

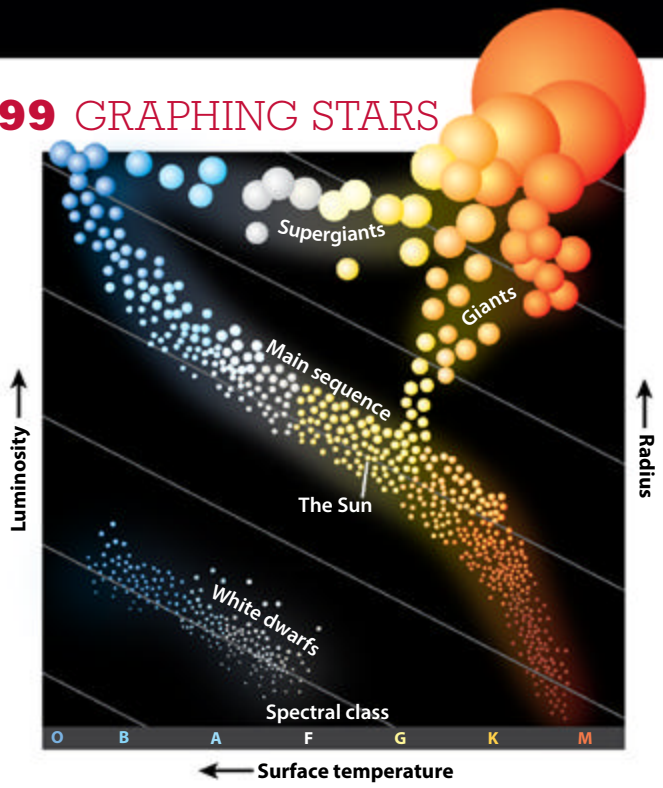
95 The world's largest single-dish fully steerable radio telescope, the Green Bank Telescope in West Virginia, began operating August 22, 2000.

96 In 1967, John Dobson created a simple and inexpensive alt-azimuth mounting for Newtonian reflector telescopes that later observers call the Dobsonian mount.

97 The Chandra X-ray Observatory, one of NASA's four Great Observatories, launched July 23, 1999.

98 From Earth, the Sun appears 30 times larger and 900 times brighter than from Neptune.

99 GRAPHING STARS



When Henry Norris Russell and Ejnar Hertzsprung each began plotting the spectral classes (temperatures) of stars against their luminosities, it unveiled the main sequence of a star's life — where it pulls power by fusing hydrogen into helium. The famous diagram also led to a range of insights on stars beyond just a way to plot their evolution.

100

1.3 MILLION

The number of Earths that could fit inside the Sun

101

EARLY EQUATORIAL

In 1824, Joseph von Fraunhofer constructed and installed the first large telescope (a 9¼-inch refractor) on an equatorial mount at Estonia's Tartu Observatory.

NASA/JPL-CALTECH/R. HURT (SSC) (WORLD); *ASTRONOMY*: ROEN KELLY (STARS); TARTU OLD OBSERVATORY (EARLY)

102 On December 13, 2011, NASA announced it had begun working on a harpoon that would obtain samples of comets.

103 Astronomers have used the Hubble Space Telescope to estimate that a whopping 125 billion galaxies populate the visible universe.

104 Some 4.7 million years ago, the currently magnitude 1.5 star Adhara (Epsilon Canis Majoris) was more than 350 light-years closer to our solar system and 160 times brighter than it is now.

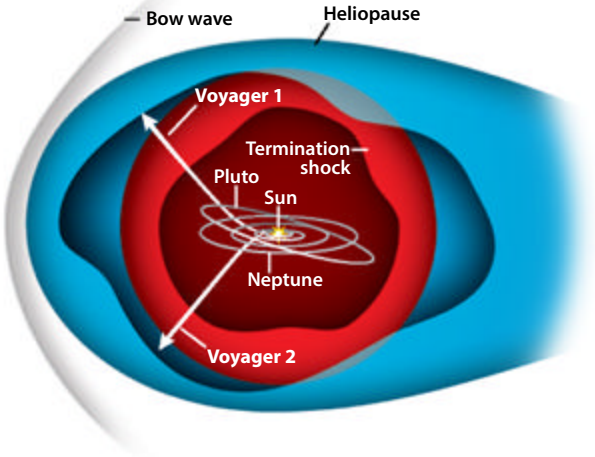
105 Lowell Observatory's privately funded Discovery Channel Telescope celebrated first light July 21, 2012.

106 The Swift gamma-ray burst (GRB) mission, launched November 20, 2004, has detected more than 1,030 GRBs so far.

107 The 60-ton Hoba iron meteorite in Namibia is the world's largest intact meteorite.

108 Greek philosopher Philolaus (c. 470–385 B.C.) originated the theory that Earth was not the center of the universe.

114 ARE WE THERE YET?



As the twin Voyager spacecraft completed pioneering missions to the outer solar system in 1989, NASA extended the program into humanity's first "interstellar mission." In 2012, scientists announced Voyager 1 had breached the heliopause — the edge of the Sun's magnetic field and the solar wind. Beyond this point, interstellar particles dominate. On board, each spacecraft carries a golden record with the sounds of Earth as a message to any space-faring aliens who might find it. Of course, it will still take tens of thousands more years to get remotely close to neighboring stars.

109 In 1889, Mizar A, the main component of the Zeta Ursae Majoris system, was the first spectroscopic binary star discovered.

110 German scientist Johann Wilhelm Ritter discovered ultraviolet radiation in 1801.

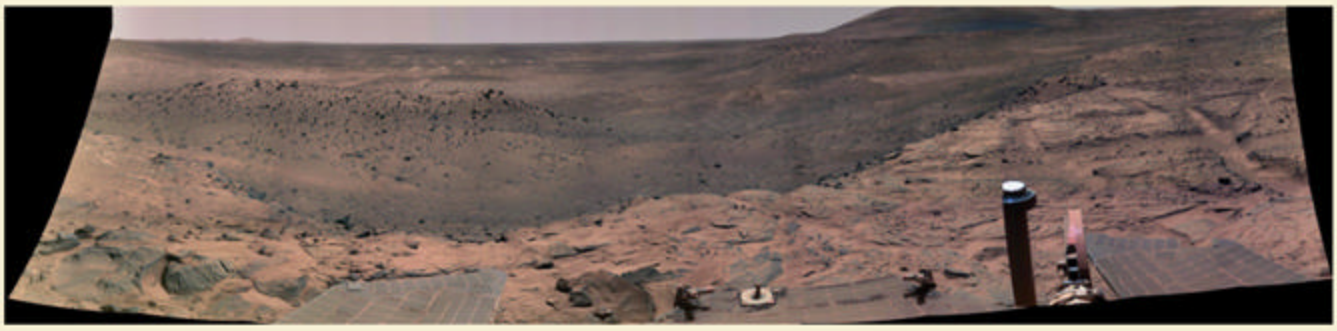
111 Earth is 3.1 million miles closer to the Sun at perihelion in early January than it is at aphelion in early July.

112 The Full Moon appears approximately 31' in diameter, or the size of a quarter at a distance of 8.85 feet.

113 The asteroid Vesta's largest crater, Rheasilvia, formed as a result of a collision about 1 billion years ago.

115 "IT'S NOT THE ANTENNA"

In the mid-1960s, Arno Penzias and Robert Wilson serendipitously discovered the cosmic microwave background — a leftover signal from our universe's hot and violent beginning — on a repurposed Bell Labs antenna in New Jersey while trying to map radio signals in the Milky Way. The find would become a decisive nail in the coffin of Big Bang doubters.



116 ROUGH ROVING

By the time NASA received the Spirit rover's final signal from Mars in March 2010, its Rock Abrasion Tool drill bit was totally worn down and one wheel had stopped working, forcing engineers to drive it backward like a getaway car on its last legs. Despite being six years past the planned three-month mission, there was good reason to try to keep going. Spirit had been assigned to explore an ancient lakebed in the 105-mile-wide Gusev Crater. The rover instead found volcanic rock. Frustrated, engineers sent Spirit on a dash for the nearby Columbia Hills, an older formation above the lowland plains. Here, the rover proved to be an able mountain climber. And in these highlands is where Spirit finally found its first evidence of rocks altered by water. It's also where the rover met its end. With dust-covered solar panels and winter approaching, the rover embarked on a risky descent down the other side of the Columbia Hills. Spirit hit an unseen obstacle, got stuck, and eventually froze.

ASTRONOMY: ROEN KELLY; AFTER NASA (VOYAGER); NASA (ANTENNA); NASA/JPL-CALTECH (ROVING)

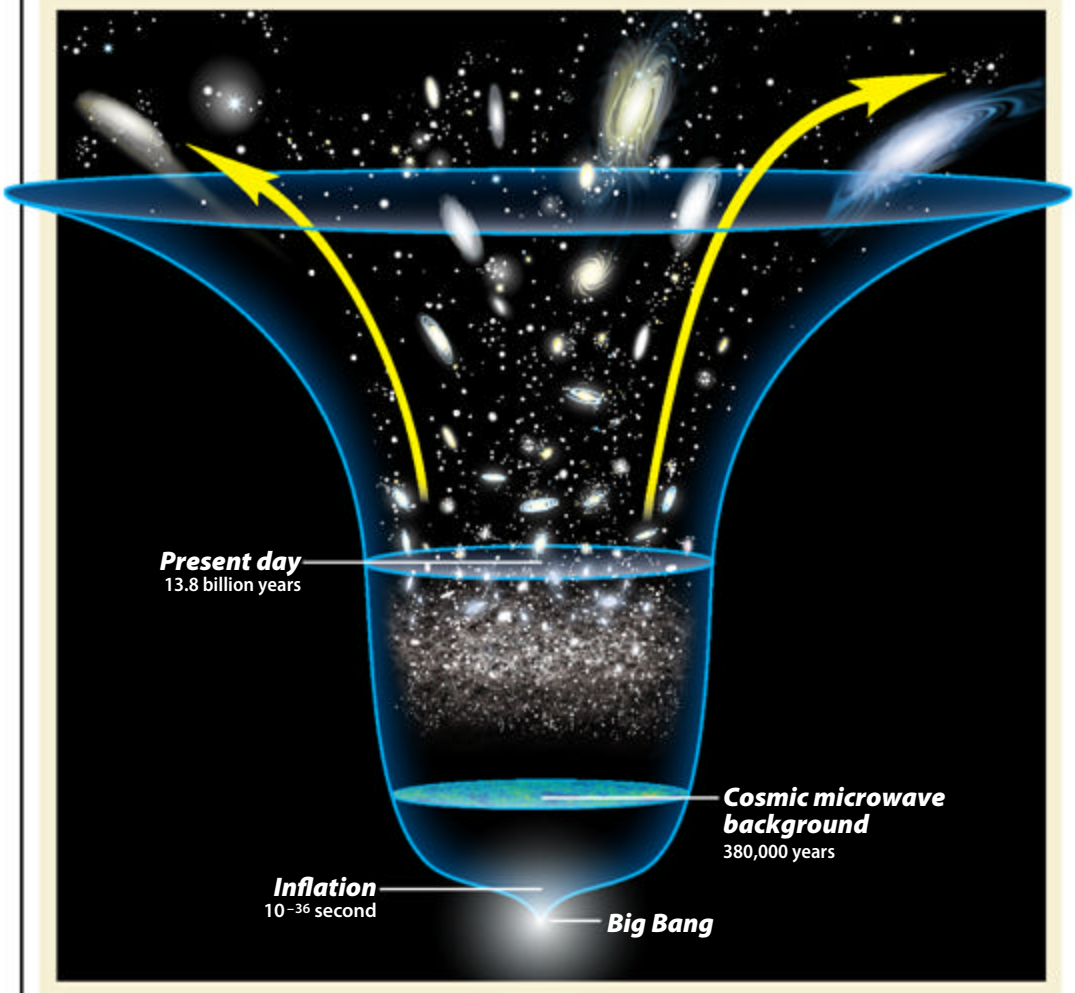
117

WHAT'S IN A NAME?

Although Comet 67P/Churyumov-Gerasimenko may not roll off most English-speakers' tongues, it is music to the ears of eager astronomers. In August 2014, the European Space Agency's Rosetta spacecraft entered orbit around this periodic comet, beginning a reconnaissance that should last through the end of 2015. As the first comet orbiter in human history, the probe will reveal more about these objects and how they behave as they approach the Sun than all previous comet missions combined.

Rosetta began its journey in March 2004, and the process of matching its orbit to the comet's took 10 years and required three gravity assists from Earth and one from Mars. When it arrived at 67P, it found a double-lobed nucleus measuring 2.5 miles across its longest dimension that reminded many scientists of a duck. This image shows the comet from 65 miles away. Parallel cliff-like features mark the comet's "head" (top), scattered boulders dot the smoother "neck," and peaks and valleys dominate the uneven terrain of the "body." On November 12, Rosetta's lander, named Philae, set down on 67P and relayed data to the mother ship for nearly 57 hours. Expect plenty more discoveries in the months ahead as Rosetta continues to monitor the comet.

ESA/ROSETTA/MPS/OSIRIS TEAM



118 INFLATING THE COSMOS

In the 1970s, most cosmologists were firmly on board with the Big Bang theory as the best description of the universe's beginning. By late in that decade, however, a number of researchers were having trouble accepting some glaring problems with the hypothesis. First, the cosmic microwave background, the Big Bang's relic radiation, appeared the same across the sky. This means the entire universe had to be the same temperature when the radiation started its journey some 380,000 years after the Big Bang. The theory couldn't explain how distant parts of the cosmos reached equilibrium. Second, the universe appeared exceptionally "flat" — balanced on a knife's edge between eternal expansion and eventual contraction — a huge coincidence that struck many astronomers as highly unlikely.

The theory's salvation came in 1980 when Massachusetts Institute of Technology physicist Alan Guth proposed cosmic inflation. He developed the idea (later expanded and refined by other cosmologists) that the universe grew at an exponential rate just a fraction of a second after the Big Bang. Before inflation, the cosmos was small enough that all parts of it could reach the same temperature, yielding a uniform background glow. And the massive expansion would have taken whatever the initial geometry happened to be and rendered it flat.

Inflation operated almost unimaginably early in cosmic history (shown just after the white glow at the bottom of this illustration). Astronomers think it started about 10^{-36} second (that is 1 trillionth of a trillionth of a trillionth of a second) after the Big Bang and lasted until 10^{-33} to 10^{-32} second after. During that brief period, the universe expanded by a factor of 10^{50}, ending the epoch about the size of a softball. This brief period of faster-than-light expansion explains the Big Bang theory's main puzzles, and most cosmologists accept it even while they wait for better observational evidence.

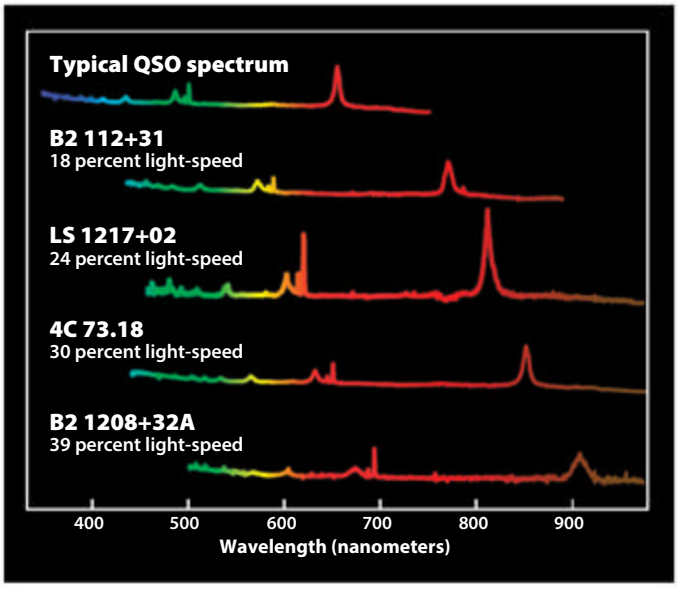
119 1.5 million square miles

Area of Oceanus Procellarum, the Moon's largest feature

120 THE SKY IS FALLING

Hundreds of thousands of shooting stars streaked across the sky in a single night in November 1833, leaving Americans in awe. Some, like Mormon leader Joseph Smith, noted it as a sign of end times at hand. But Denison Olmsted's published account of the event showed the shooting stars had all originated from the same region of sky — near the constellation Leo — prompting the name "Leonids." He also noted that the shower had not been visible across other parts of the world and correctly proposed that particles in space had caused the event instead of atmospheric phenomena, as had been previously suspected. It was the start of meteor science.

121 A SHIFT IN PERSPECTIVE



The Doppler effect, first proposed in 1842 by Austrian physicist Christian Andreas Doppler, is a change in wavelength caused by the motion of the source. Objects like stars and nearby galaxies can show shifts toward the red or blue end of the spectrum, depending on whether they are receding from or approaching us, respectively. Another source of redshift comes from the expansion of the universe, where the farther an object is from us, the larger its redshift (the faster it moves). This diagram compares four quasi-stellar objects (QSO) speeding away from us to a non-moving one.

122 On the Fourth of July in 2005, a copper slug shot from NASA's Deep Impact spacecraft struck Comet 9P/Tempel, releasing material the main craft then analyzed.

123 British astronomer N. R. Pogson standardized the magnitude system in 1856.

124 In 2009, nearly a billion people participated in activities around the world during the International Year of Astronomy.

125 The maximum size of Mars in our sky is 25.1", which is the same as a quarter seen from 650 feet away.

126 A meteor exploded above Chelyabinsk, Russia, on February 15, 2013, raining meteorites over the countryside and indirectly causing more than 1,500 injuries (most from windows whose glass broke due to the shock wave).

127 The tallest mountain in the solar system — rising 14 miles from its base — is the central peak of the crater Rheasilvia on the asteroid Vesta.

128 Comet Ikeya-Seki (C/1965 S1), one of the brightest comets ever recorded, blazed in the daytime sky October 21, 1965.

129 The Convection Rotation and Planetary Transits spacecraft, which operated from 2006 to 2012, made the first photometric detection of oscillations in stars other than the Sun.

130 In 1884, representatives from the 22 countries attending the International Meridian Conference in Washington, D.C., chose the meridian passing through the Royal Observatory, Greenwich, as the Prime Meridian (longitude = 0°).

131 On September 12, 1962, President John F. Kennedy gave the "We choose to go to the Moon" speech to a crowd at Rice University in Houston.

132 Between 1645 and 1715, during a period now called the Maunder minimum, sunspots were rare.

133 El Gordo (ACT-CL J0102–4915), the largest known galaxy cluster, contains some 4.3 million billion times the mass of the Sun.

134 Of the 8,768 stars brighter than magnitude 6.5, only eight are brighter than magnitude 0.5.

135 Sagittarius the Archer contains 15 Messier deep-sky objects, more than any other constellation.

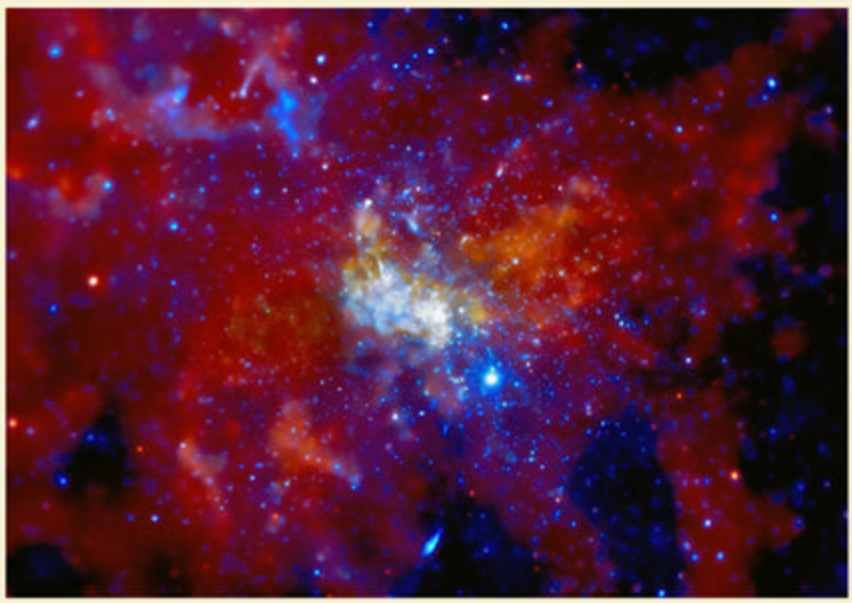
136 Scientists have measured uranium and lead in meteorites to refine when the first solids in the solar system began forming — 4.567 billion years ago.

137 BABY'S HUNGRY

From data they acquired using the baseline interferometer of the National Radio Astronomy Observatory in Green Bank, West Virginia, on February 13 and 15, 1974, American astronomers Bruce Balick and Robert Brown discovered a bright radio source at the center of our galaxy.

The observers pointed out similarities with quasars and other objects powered by supermassive black holes, but the evidence of the true nature of this mysterious object, known as Sagittarius A* (pronounced "A-star"), didn't come until later.

Since then, astronomers have estimated that the mass of the object is approximately 4 million times that of the Sun. They obtained that result by measuring the motions of stars orbiting the unseen object. The only thing that can have that much mass in such a small space is a black hole. Sgr A* lies some 27,200 light-years from Earth. The Swift space telescope monitors it on a daily basis.



Sagittarius A* is the supermassive black hole at the Milky Way's core.

ASTRONOMY: ROEN KELLY (INFLATING); ENGRAVING BY ADOLF VOLLMY (SKY); *ASTRONOMY:* ROEN KELLY, AFTER C. PILACHOWSKI, M. CORBIN/NOAO/AURA/NSF (PERSPECTIVE); NASA/CXC/MIT/F. K. BAGANOFF, ET AL. (HUNGRY)

138

HEAT SEEKER

During a 10-month-long mission in 1983, NASA's Infrared Astronomical Satellite became the first space telescope to conduct a survey of the sky in infrared wavelengths.

139 Saturn's icy moon Iapetus is susceptible to landslides up to 50 miles long.

140 American astronomer Edwin Hubble invented the tuning fork diagram in 1936 to classify galaxies by their appearances.

141 The Mars Global Surveyor, which circled the Red Planet in a polar orbit every 117 minutes and 39 seconds from 1997 to 2006, always saw Mars' surface features under identical lighting conditions.

142 The Soviet Venera 7 was the first spacecraft to land successfully on another planet — Venus — December 15, 1970.

143 Each of the two opposing beams of the Large Hadron Collider typically contains 2,808 bunches with some 100 billion protons in each bunch.

144 In the 85 days it was active on the martian surface in 1997, the Mars Pathfinder lander made more than 8.5 million measurements of martian air pressure, temperature, and wind speed.

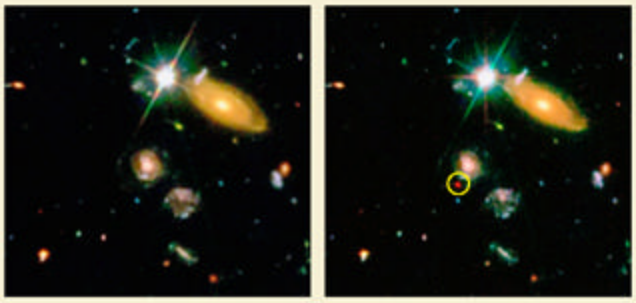
145 The largest constellation in the sky, Hydra the Water Snake, is 19 times bigger than the smallest constellation, Crux the Southern Cross.

146 On January 17, 1982, explorers found Allan Hills A81005, the first lunar meteorite.

147 In 1665, Italian astronomer Giovanni Cassini classified Jupiter's Great Red Spot as a permanent feature.

148 The first planetarium opened in Munich in 1923.

149 In 1916, German physicist Karl Schwarzschild solved Albert Einstein's general theory of relativity field equations and derived the size of the event horizon of a non-rotating black hole.



150 NO ONE SAW IT COMING

When American astronomer Edwin Hubble discovered in 1929 that the universe was expanding, scientists assumed that the attractive force of gravity eventually would slow down this growth. They were wrong. In 1998, two teams of astronomers — one led by Saul Perlmutter of the University of California, Berkeley, and the other by Brian Schmidt of Mount Stromlo Observatory in Australia — announced that a mysterious force is causing cosmic expansion to speed up.

Both groups pinned down this so-called dark energy by observing distant type Ia supernovae with the Hubble Space Telescope and several large ground-based instruments. Astronomers think most of these exploding stars occur in binary systems in which one member is a white dwarf and the other a red giant. The white dwarf's powerful gravity pulls in material from the red giant's bloated atmosphere, and once the former reaches a critical threshold around 1.4 times the Sun's mass, it detonates.

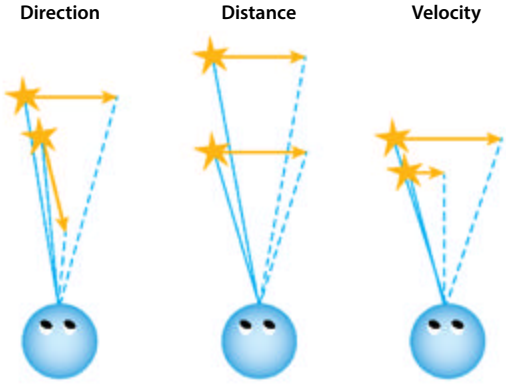
Because type Ia explosions arise from nearly identical progenitor stars, their peak luminosities also match. So, once scientists measure how bright the supernova appears, they can calculate its distance. Perlmutter's and Schmidt's teams found that the farthest type Ia explosions were fainter than their distances implied. The only way this makes sense is if some force, dubbed "dark energy," is accelerating cosmic expansion. Measurements made by the Planck satellite show dark energy accounts for about 68 percent of the mass-energy content of the universe.

These images show a part of the famous Hubble Deep Field before and after a type Ia explosion. The original photograph from 1995 (left) shows a deep view of the cosmos stretching billions of light-years from Earth. The image on the right comes from seven years later and shows Supernova 2002dd (circled). At a distance of 8 billion light-years, this explosion helped shed light on when dark energy started to dominate the universe.

151 STARS DO MOVE

Although observers had speculated for several thousand years that the stars were not immobile, it wasn't until 1718 that proof came. In that year, English astronomer Edmond Halley noticed that three bright stars — Sirius, Arcturus, and Aldebaran — were more than 0.5° away from positions given by the Greek astronomer Hipparchus in the second century B.C.

This shift in apparent position on the sky over time — now called proper motion — occurs across our line of sight. The amount of a star's proper motion depends on several factors. The diagram shows that a star approaching Earth (left) appears to move across the sky less than one traveling at right angles to Earth. At center, two stars with equal velocities lie at different distances; the nearer changes position more than the farther one. The stars at right travel at different speeds, and one — although more distant than the other — has a larger proper motion.



152 ZIPPITY DO DA!

Edward Emerson Barnard wasn't the first to spot Barnard's Star, but in 1916 the astronomer became the first to measure its extreme movement across the sky. The star is the second-nearest stellar system to Earth at 6 light-years away and drifts about 1 Moon width in 180 years, faster than any other.

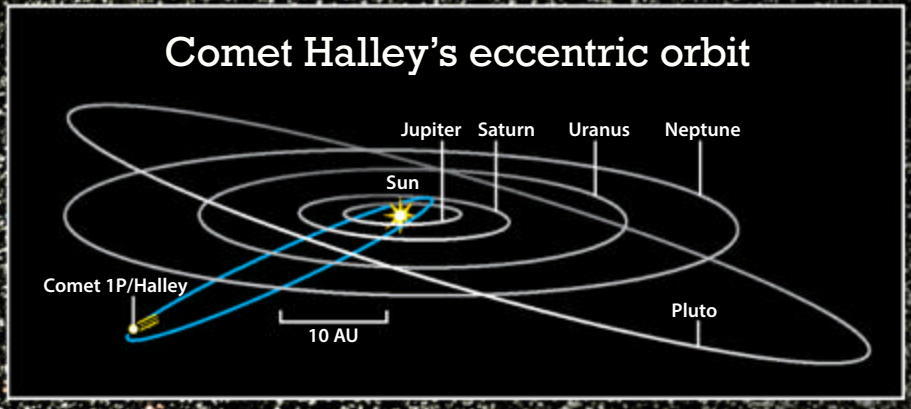
JPL/NASA (HEAT); NASA/J. BLAKESLEE (JHU) (NO ONE); ASTRONOMY: ROEN KELLY (STARS)

153

COMING BACK AROUND

Tycho Brahe had already proved a century earlier that comets were objects located beyond the Moon's orbit, not aberrations in Earth's atmosphere, when an English scientist named Edmond Halley began studying them in 1687. He started applying his friend Isaac Newton's just published equations explaining the mechanics of planetary motion and the effects of gravity to historical comet observations. In doing so, Halley was able to describe the paths of 24 comets in his 1705 *Astronomiae cometicae synopsis* ("Synopsis of the Astronomy of Comets"), becoming the first to definitively say these objects could orbit the Sun. He also made a critical connection between comet observations in 1531, 1607, and 1682, concluding that each was of the same object and predicting its return in 1758. Although Halley died 17 years before the comet's return, it now bears his name, 1P/Halley, and returns to our skies every 75.3 years (shown here in 1986). Mark your calendars for 2061.

ALFRED LILGE (COMET); *ASTRONOMY*: ROEN KELLY (DIAGRAM)



The Andromeda Galaxy showcases spiral arms teeming with bright star clusters, pink stellar nurseries, and dark dust lanes.

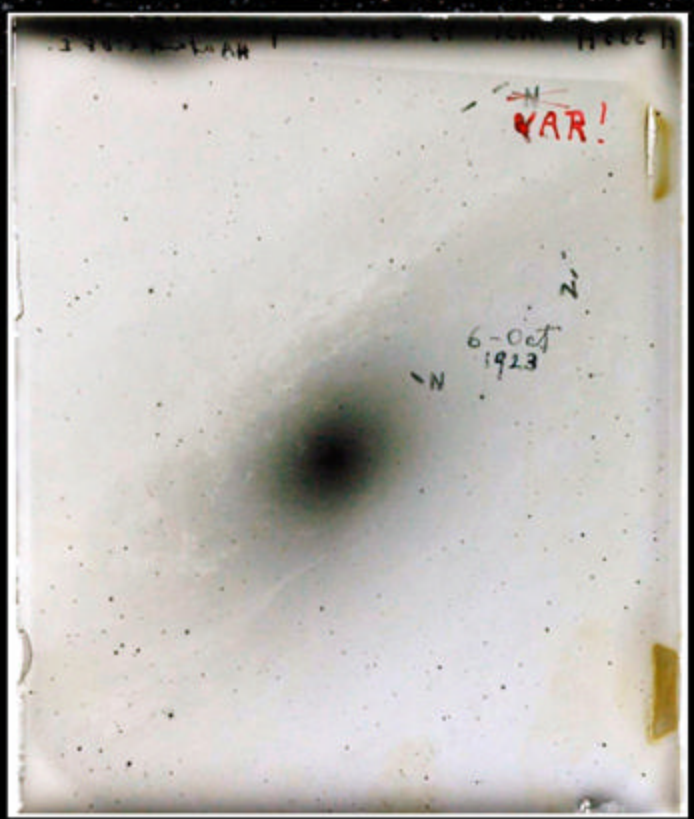
154

AND THEN THERE WERE TWO

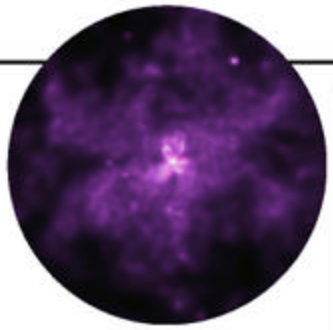
Thanks largely to the exploits of the Hubble Space Telescope, astronomers now know that some 125 billion galaxies inhabit the universe. So it often surprises people to learn that the population of known galaxies just a century ago was one — the Milky Way *was* the entire cosmos.

The universe's galactic count doubled in 1923 when the space telescope's namesake, American astronomer Edwin Hubble, found a Cepheid variable star while examining photographic plates of what was then called the "Andromeda Nebula." Using the period-luminosity relationship Henrietta Leavitt discovered during the previous decade, Hubble deduced that the nebula had to lie far beyond the outer boundaries of the Milky Way and must therefore be a separate galaxy. Other galaxies soon popped up, and our picture of the cosmos started to take on its modern look.

BOB FERA (M31); COURTESY OF THE CARNEGIE OBSERVATORIES (CEPHEID VARIABLE)



When Edwin Hubble discovered a Cepheid variable star in the Andromeda "Nebula," he crossed out the "N" (signifying a nova) and wrote "VAR!" (for variable).



155
DYNAMIC DUO

NGC 6240 in the constellation Ophiuchus represents the ongoing merger of two spiral galaxies. In 2001, the Chandra X-ray Observatory revealed that NGC 6240's core harbors two supermassive black holes (the side-by-side bright spots at center), the first such pair ever discovered.

157 The largest refractor in the world, the 40-inch telescope at Yerkes Observatory in Wisconsin, began operation in 1897.

158 In 1856, physicists created the first silver-coated glass telescope mirror, replacing the solid metal mirrors that had been used up to that point.

159 In 1930, American astronomer John Strong developed a process to coat telescope mirrors with aluminum, which is more reflective and durable than silver.

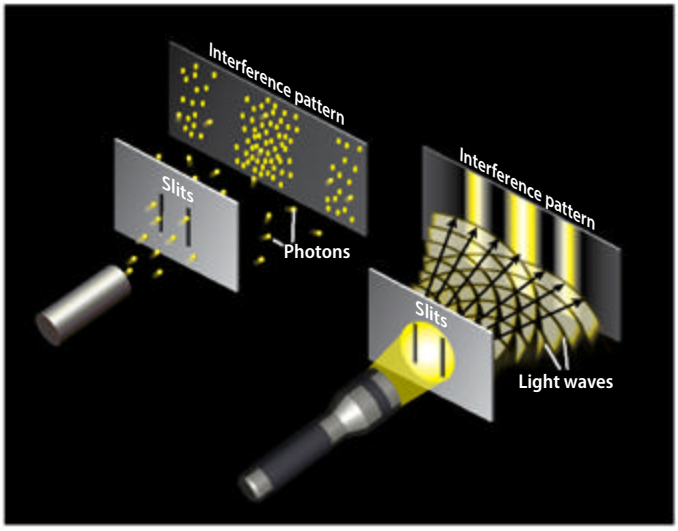
160 The 190-mile-wide Vredefort crater in South Africa is the largest verified impact crater on Earth.

161 The International Space Station completes an orbit of Earth in about 90 minutes.

162 In 2012, the International Astronomical Union redefined the astronomical unit's length as a constant 149,597,870,700 meters.

163 German astronomer Johannes Franz Hartmann made the first detection of the interstellar medium in 1904.

156 PARTICLE OR WAVE?



In the 1660s, two theories about the nature of light appeared. One described light as having characteristics similar to a wave (think water ripples). The other said that it shows properties similar to the way particles behave. Through the years, one theory would attain greater popularity, then the other would take over. Research from the early 20th century proved that both are true, and scientists refer to this blend as the wave-particle duality.

166 THE PROBLEM WITH THE SUN

By all accounts, Raymond Davis Jr. was a hardheaded guy. He built a detector 4,800 feet underground in a South Dakota gold mine in hopes of capturing the elusive neutrinos — tiny chargeless particles that rarely interact with matter — that physicists predicted should be streaming from the Sun. The experiment consisted of a massive 100,000-gallon vat of cleaning fluid using Earth above as a shield from unwanted interference, like other particles from space. If a neutrino collided with a chlorine atom, it would transform the atom into radioactive argon, which the detector would pick up. But years went by, and Davis found nothing.

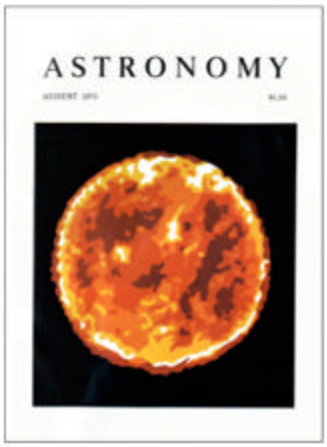
After many adjustments, he eventually managed to detect solar neutrinos, but at one-third of the predicted amount. In physics, this became known as the solar neutrino problem. It was solved in 2001 when ultra-sensitive underground detectors discovered even more elusive kinds of neutrinos, which change their type on their way to Earth. The missing neutrinos had been there, invisible, all along. The mysterious discovery won Davis a share of the 2002 Nobel Prize in physics. Researchers still use the same mine for detecting exotic particles today, now with a focus on the much anticipated dark matter.

164 On April 12, 1961, Russian cosmonaut Yuri Gagarin became the first person to orbit Earth; American astronaut John Glenn followed in his path 10 months later.

165 In 2011, the MErcury, Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) spacecraft became the first to orbit the innermost planet.

167 **1 billion seconds**
The time it takes the light from a star 31.7 light-years away to reach Earth

NASA/CXC/SAO/E. NARDINI, ET AL. (DUO); *ASTRONOMY*: ROEN KELLY (PARTICLE); BNL (PROBLEM)



168

PRINT PRIDE

AstroMedia Corporation published the first issue of *Astronomy* in August 1973.

169 Within 32.6 light-years (10 parsecs) of the Sun lie 358 stars and brown dwarfs.

170 NASA's Dawn spacecraft will become the first to visit the inner solar system asteroids Vesta (2011) and Ceres (2015).

171 With a diameter about 1,700 times that of the Sun, the star UY Scuti is the largest found so far.

172 In just 42 hours from October 23 to 24, 2007, Comet 17P/Holmes brightened some 478,000 times.

173 In 2012, the Beehive Cluster (M44) became the first open cluster in which astronomers found planets orbiting stars.

174 Humans have tried to send 51 spacecraft to Mars: 24 by the United States, 21 by Russia (or the Soviet Union), three by the European Space Agency, and one each by China, India, and Japan.

188 START ME UP!

The universe expanded for 13.8 billion years before Belgian priest Georges Lemaître proposed his "cosmic egg" theory as a consequence of general relativity. The term *Big Bang* eventually emerged from famed skeptic Fred Hoyle and was taken as an insult, but it's Lemaître who gets the last laugh (even if Edwin Hubble often gets the credit). Observations proved that most galaxies are whizzing away. And all hope for an unchanging universe was lost when the cosmic microwave background was found in 1964, confirming the remains of our universe's rapid expansion and yet another of Lemaître's predictions.

180 Christopher Columbus impressed natives on Jamaica by predicting the lunar eclipse of February 29, 1504.

181 Astronomers discovered the first millisecond pulsar (one with a rotational period between 1 and 10 milliseconds), PSR 1937+21, in 1982.

182 Mercury's temperature varies from –280° F on its night side to 800° F during the day.

183 The Moon takes 27.3 days to orbit Earth once, but 29.5 days to go from New Moon back to New Moon.

184 The Pioneer 5 spacecraft confirmed the existence of interplanetary magnetic fields in 1960.

185 Italian astronomer and Catholic priest Giuseppe Piazzi discovered the first asteroid, Ceres, on January 1, 1801.

186 The Arecibo telescope, which went into operation in 1963, is the world's largest single-aperture radio telescope with a collecting area of 790,000 square feet.

187 The Magellan spacecraft — the first interplanetary mission launched from a space shuttle — mapped nearly all of Venus' surface from 1990 to 1994.

189 522,000 LIGHT-YEARS

The diameter of the largest spiral galaxy, NGC 6872

175 With speeds of nearly 160,000 mph, the meteors of the Leonids are the fastest of any shower.

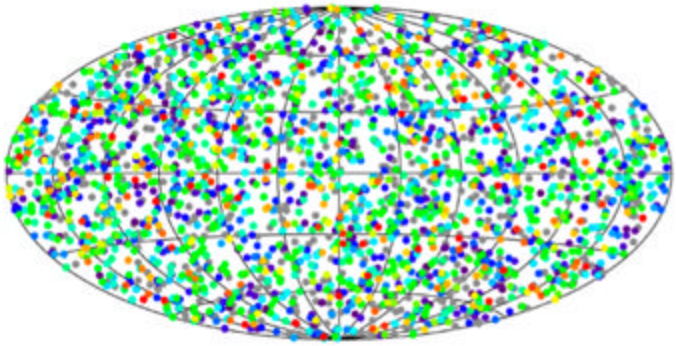
176 At its equator, Jupiter rotates at 27,900 mph, more than 27 times as fast as Earth.

177 German physicist William Röntgen discovered and named X-rays in 1895.

178 NASA's Uhuru, launched from Kenya, became the first orbiting X-ray telescope in 1970.

179 Only one lunar crater with a diameter larger than 30 miles begins with the letters Q or X: Quetelet and Xenophanes.

190 BURSTING WITH SURPRISES



In 1967, four orbiting Vela satellites detected a short, intense burst of gamma rays. More than a dozen gamma-ray bursts followed in the next three years. Because the Vela system was a military project (searching for violations of the Nuclear Test Ban Treaty), however, astronomers were in the dark until 1973. The Compton Gamma-Ray Observatory, whose nine-year mission ended in 2000, recorded the 2,704 bursts seen here (red dots are the most powerful events, purple the least), and the all-sky distribution proved they originate in the distant universe.

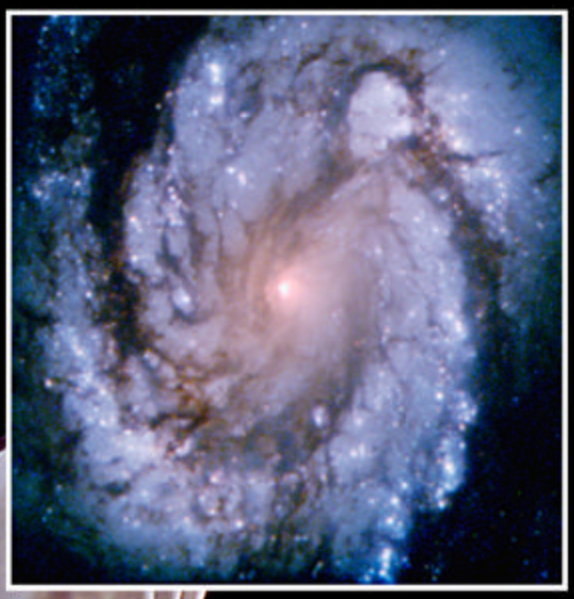
ASTRONOMY (PRINT); *ASTRONOMY*: ROEN KELLY (START); NASA/MSFC (SURPRISES)

191

NO MATTER WHAT SHAPE

Astronomers were feeling a mix of anxiety and excitement April 25, 1990, as astronauts aboard the space shuttle *Discovery* prepared to deploy the Hubble Space Telescope. Lifted above the distorting effects of Earth's turbulent atmosphere, the school-bus-sized orbiting observatory promised clearer views of the heavens than humans had ever seen. But there was always the possibility that something could go wrong.

Within weeks, promise had turned to debacle. Hubble's initial images showed a problem with the 2.4-meter main mirror that prevented the telescope from achieving a sharp focus. The blurry pictures were little better than what astronomers could achieve with telescopes on the ground. Fortunately, NASA designed Hubble for regular servicing missions. When astronauts on the shuttle *Endeavour* visited the observatory in December 1993, they installed new instruments that corrected the scope's eyesight. And the rest is history.



Spiral galaxy M100 looks blurry through a first-generation Hubble instrument (top) but sharpens to crystal clarity through a second-generation camera installed during the initial servicing mission.

NASA/SMITHSONIAN INSTITUTION/LOCKHEED CORPORATION (HUBBLE SPACE TELESCOPE); NASA (M100)

The space shuttle *Discovery's* robotic arm grapples the Hubble Space Telescope as astronauts prepare to release the observatory April 25, 1990.

— *Continued on page 52*

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

March 2015: Darkness at midday

People will travel thousands of miles for the chance to glimpse delicate detail in the Sun's corona during a total solar eclipse. Their next opportunity arises March 20 when the Moon completely hides the Sun's photosphere for viewers in the waters south and east of Iceland. LESLIE MARCZI

Spring returns to Earth's Northern Hemisphere in March, and, this year at least, the annual rebirth of our home world coincides with the evening appearance of several bright planets. Brilliant Venus rules the western sky, where it stands near the subtler glow of ruddy Mars. In the opposite direction, Jupiter dominates the starry background. Just one month past its annual peak, the giant planet climbs higher with each passing day. Although the morning sky seems subdued in comparison, you won't want to miss Saturn as it adds to the luster of Scorpius the Scorpion.

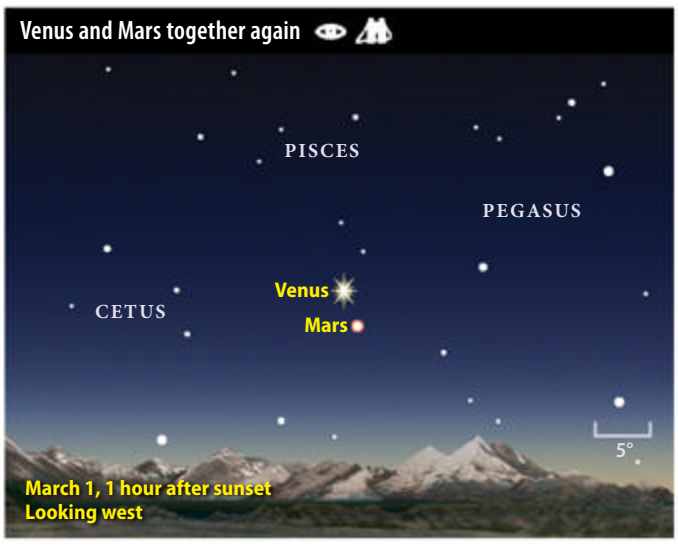
Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

But the month's biggest event occurs in daylight hours. On March 20, the New Moon passes directly in front of the Sun and brings a **total solar eclipse** to observers along a path that arcs south and east of Iceland. Although the track of totality lies mostly over open water, it does make landfall in the Danish Faroe Islands (located approximately halfway between Iceland and Norway) and Norway's island of Spitsbergen. Maximum eclipse occurs east of Iceland, where the Moon blocks the Sun for 2 minutes and 47 seconds.

People across most of Europe experience a significant partial eclipse. From the United Kingdom, Ireland, and Scandinavia, the Moon covers more than 80 percent of the Sun. Residents in the rest of northern Europe witness at least 60 percent coverage. The southern limit of partial eclipse visibility stretches across northern Africa and then through Saudi Arabia, Iraq, and Iran before ending in northern China.

The night sky offers its own rewards, however, and they are available to viewers across the globe. As March opens, **Venus** and **Mars** hang near each other in the western sky as darkness falls. Venus shines at magnitude –3.9 and shows up within 20 minutes of sunset. Mars glows at magnitude 1.3 — less than 1 percent as bright as its neighbor — and the sky needs to darken considerably for it to emerge. By 7 P.M. local time, both appear conspicuous. Venus stands 15° high, and Mars hangs 4° below it. Binoculars will deliver the best views of the planetary pair.

As March progresses, the apparent gap between the two worlds grows. Mars orbits farther from the Sun than does Earth and thus moves more slowly than our planet. The relative motion soon will carry Mars behind the Sun from our viewpoint. Meanwhile, Venus follows a faster inside track and is pulling away from the solar glow. By March 21, 13° separate the two planets.



Brilliant Venus points the way to ruddy Mars in early March when the two planets lie near each other in evening twilight. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

RISING**MOON**

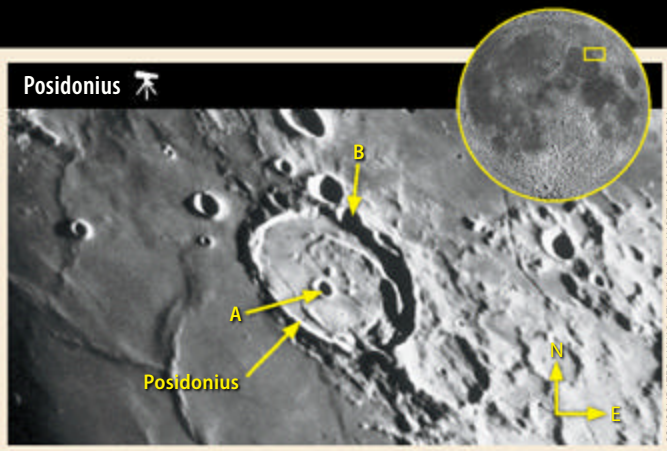
A fortnight of fabulous features

Packed with detail, the 59-mile-wide crater Posidonius ranks near the top of every Moon-lover's list. This ancient impact feature stands out in the Moon's northeastern quadrant. Its lava-filled interior sports cracks, jumbled peaks that poke up from the floor, an off-center craterlet, and bright segments where the walls have slumped inward.

Unlike craters that vanish at Full Moon, Posidonius boasts a bright rim with a face full of detail. The various shades of gray come from differences in reflectivity — what astronomers call "albedo." The dark lava on the crater's floor contrasts nicely with the bright specks of small impact events and the long arc of a slumped terrace whose face aims skyward.

This mesmerizing scenery lasts through March's first week until sunset arrives over the region the evening of the 9th. The shadows and highlights will be reversed compared to the image at right, which shows the view shortly after sunrise (which occurs on the 25th this month). As sunset approaches, watch the features become increasingly exaggerated as their shadows lengthen. Also take note of two companion craters. Posidonius B is a conspicuous 9-mile-wide gash on the main crater's northeastern rim, while Posidonius A is the slightly smaller craterlet just west of the big impact feature's center. Both have the sharp edges of youth, though in the Moon's case, young means roughly 100 million years old.

Posidonius



CONSOLIDATED LUNAR ATLAS/UA/LPL; INSET: NASA/GSFC/ASU

Intricate detail covers the floor of 59-mile-wide Posidonius, making the crater a worthy target whenever the Sun illuminates it.

Many people think Posidonius is named after Poseidon, the Greek god of the sea. But the crater actually takes its name from the Greek astronomer and philosopher Posidonius, who lived from around 135 to 51 B.C.

By then, however, a third solar system object has joined the pair. A slender crescent Moon passes 1° south (to the left) of Mars that evening. A slightly fatter Moon slides 3° south of Venus the next night. As March closes, Venus stands 17° above Mars, and the Red Planet appears about 10° above the western horizon 45 minutes after sunset.

When viewed through a telescope, Venus shows slight changes this month. On the 1st, its disk measures 12" across and the Sun illuminates 86 percent of it. By the 31st, the planet spans 14" and appears 78 percent lit. Mars pales considerably in comparison: Its 4"-diameter disk shows no detail.

Lurking in the background of the Venus-Mars tandem is the ice giant planet **Uranus**. A 6th-magnitude object, it usually is not easy to spot when low in the sky, but March 4 is an exception. That evening, the distant world appears less

— Continued on page 50

METEORWATCH

Spring's dusty evening glow

Trillions of meteoroids show up on March evenings, but you need ideal conditions to see them. Only a few of these fine dust particles penetrate Earth's atmosphere and burn up in the process, creating the bright streaks of light called meteors. Most scatter across the inner solar system in the plane of the planets' orbits.

Moonless evenings in March are the best time to see this dust. Sunlight reflects off the dust, creating the beautiful and ethereal zodiacal light. Find a dark observing site, and gaze due west as twilight fades to night. As soon as the Milky Way appears, look for a faint cone of light extending along the ecliptic from the horizon to Taurus. Try your luck any clear evening from around March 8 to 21.

Zodiacal light

Mid-March provides observers with their best chance this year to view the zodiacal light's subtle glow after sunset. ROB RATKOWSKI

OBSERVING HIGHLIGHT You won't get a better chance to track down Uranus than on the evening of March 4, when brilliant Venus passes 0.1° north of it.

STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. March 1
10 P.M. March 15
9 P.M. March 31

Planets are shown at midmonth

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light

MARCH 2015

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

Calendar of events

3 The Moon passes 5° south of Jupiter, 3 A.M. EST

4 Venus passes 0.1° north of Uranus, 3 P.M. EST

5 The Moon is at apogee (252,516 miles from Earth), 2:33 A.M. EST

Asteroid Eleonora is at opposition, 9 A.M. EST

Full Moon occurs at 1:05 P.M. EST

6 Asteroid Iris is at opposition, 8 A.M. EST

9 Asteroid Juno is stationary, 11 A.M. EDT

11 Mars passes 0.3° north of Uranus, 4 P.M. EDT

12 The Moon passes 2° north of Saturn, 4 A.M. EDT

13 Last Quarter Moon occurs at 1:48 P.M. EDT

14 Saturn is stationary, 6 P.M. EDT

18 The Moon passes 4° north of Neptune, 10 P.M. EDT

19 The Moon passes 5° north of Mercury, 1 A.M. EDT

The Moon is at perigee (222,192 miles from Earth), 3:38 P.M. EDT

20 New Moon occurs at 5:36 A.M. EDT

Vernal equinox occurs at 6:45 P.M. EDT

SPECIAL OBSERVING DATE

20 A total solar eclipse occurs along a narrow path that cuts across the waters south and east of Iceland.

21 The Moon passes 0.1° north of Uranus, 7 A.M. EDT

The Moon passes 1.0° south of Mars, 6 P.M. EDT

22 Asteroid Nysa is at opposition, noon EDT

The Moon passes 3° south of Venus, 4 P.M. EDT

25 The Moon passes 0.9° north of Aldebaran, 3 A.M. EDT

27 First Quarter Moon occurs at 3:43 A.M. EDT

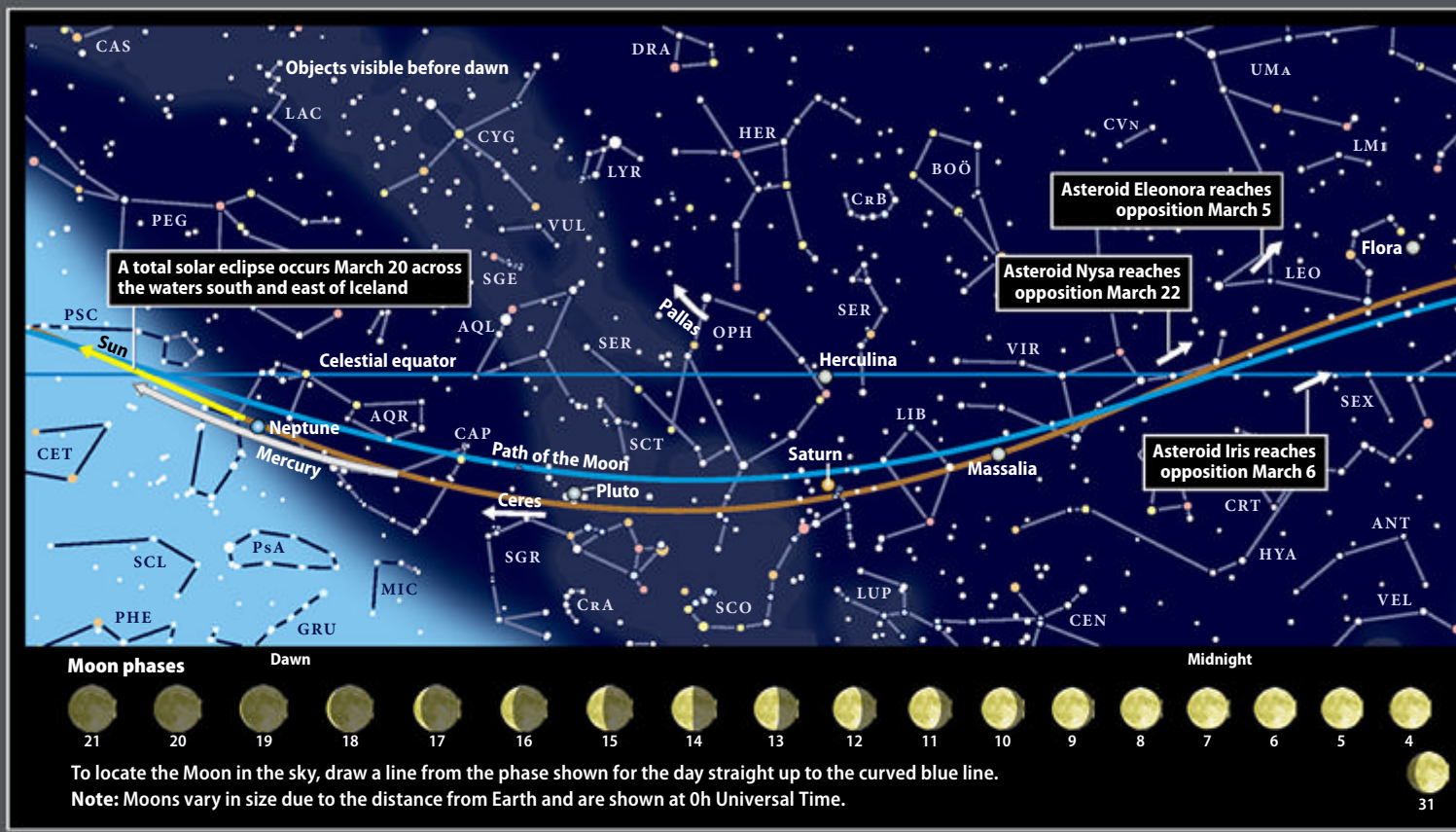
30 The Moon passes 6° south of Jupiter, 6 A.M. EDT

See tonight's sky in Astronomy.com's STARDOME

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

PATH OF THE PLANETS

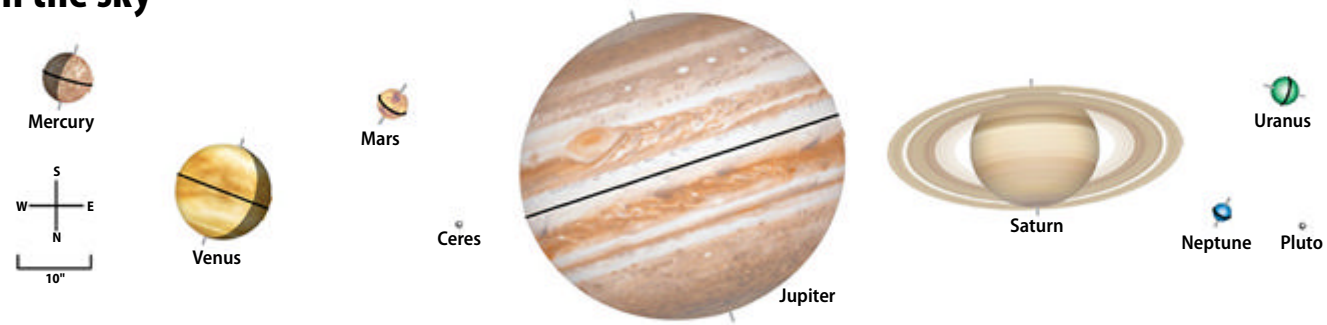
The planets in March 2015



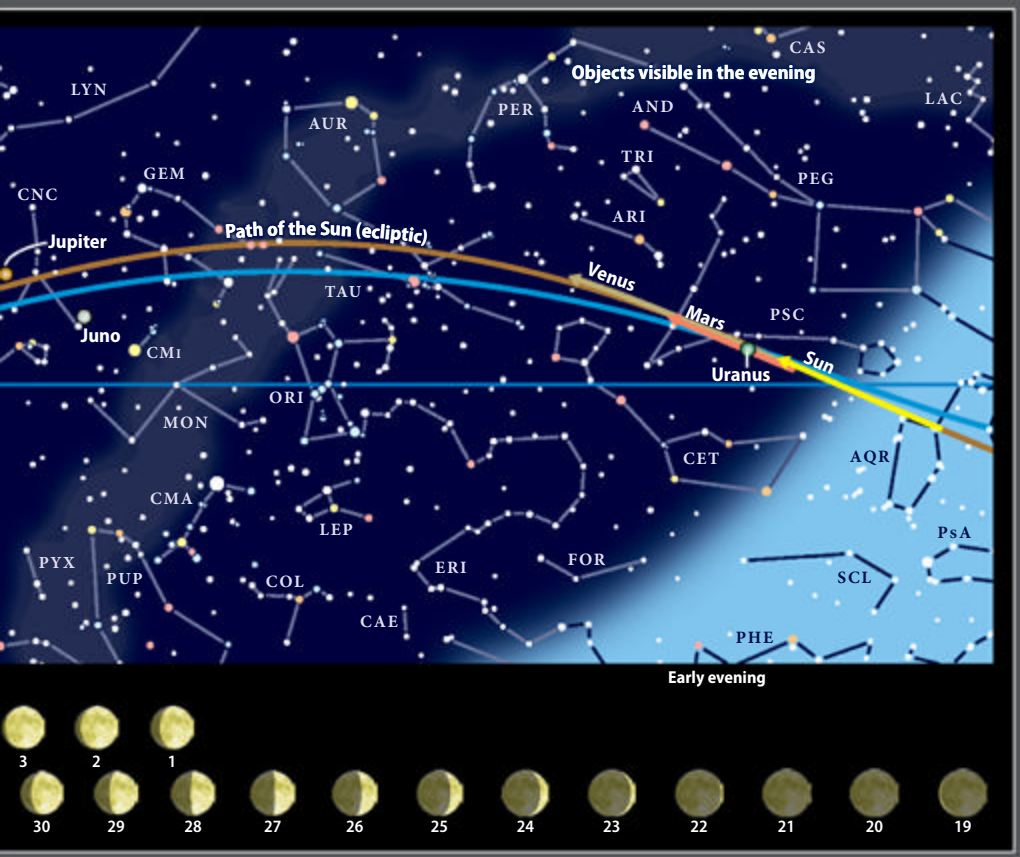
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

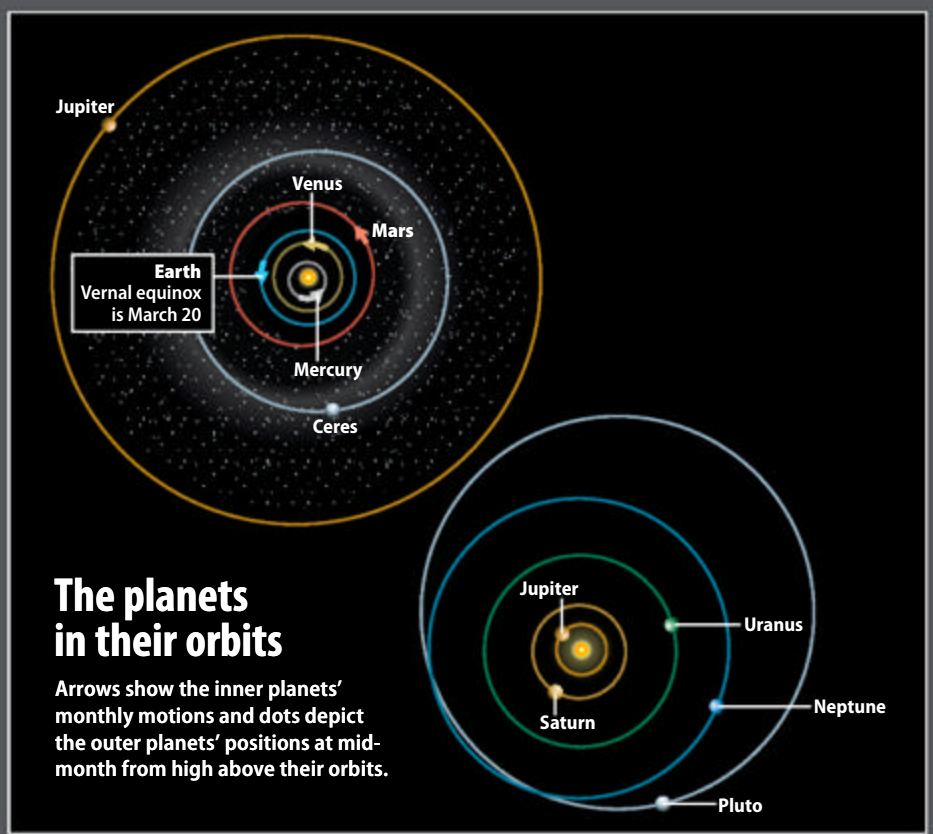
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.



Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	March 1	March 15	March 15	March 15	March 15	March 15	March 15	March 15	March 15
Magnitude	0.0	–3.9	1.3	9.1	–2.4	0.4	5.9	8.0	14.2
Angular size	6.5"	12.7"	4.1"	0.4"	43.3"	17.3"	3.4"	2.2"	0.1"
Illumination	65%	83%	98%	98%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.028	1.309	2.294	3.240	4.549	9.597	20.925	30.921	33.180
Distance (AU) from Sun	0.462	0.721	1.438	2.873	5.343	9.967	20.001	29.967	32.834
Right ascension (2000.0)	21h04.7m	1h39.7m	1h04.3m	19h45.6m	9h04.3m	16h12.6m	0h56.1m	22h38.6m	19h04.4m
Declination (2000.0)	–17°27'	10°19'	6°30'	–23°55'	17°46'	–19°01'	5°19'	–9°22'	–20°31'



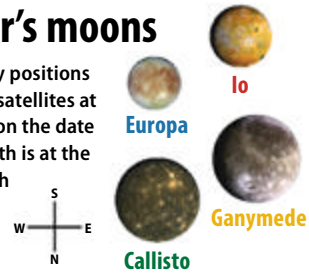


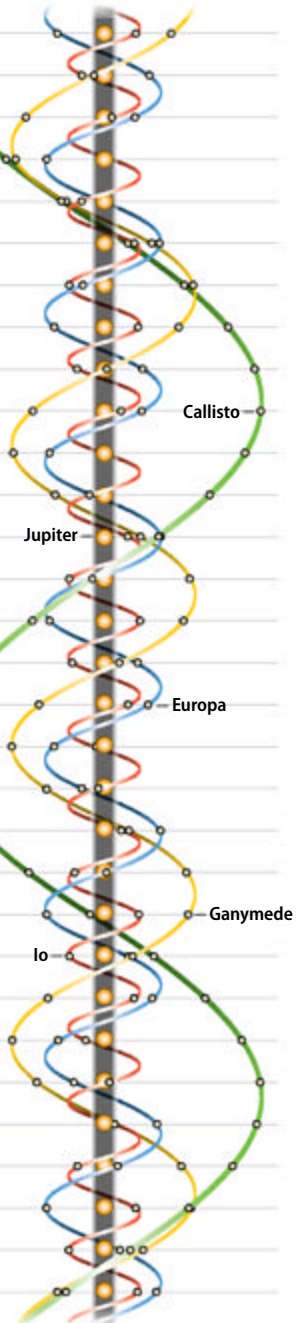
The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

— Continued from page 45

WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (west)	Jupiter (southwest)	Mercury (southeast)
Mars (west)		Saturn (south)
Jupiter (southeast)		Neptune (east)
Uranus (west)		

than a Full Moon's diameter below Venus. Look for the two through binoculars or a telescope some 10° high and due west at 7:30 P.M. local time, once the sky has darkened totally.

While Venus dominates the western sky after sunset, **Jupiter** does the same in the east. Although the gas giant reached opposition and peak visibility in February, its appearance hardly suffers in March. Jupiter gleams at magnitude –2.4 at midmonth — only the Moon and Venus shine brighter. And the solar system's largest planet climbs high earlier on March evenings, appearing at least two-thirds of the way to the zenith (the point directly overhead) for about three hours.

Jupiter lies in Cancer the Crab, a faint constellation nestled between Gemini the Twins and Leo the Lion. The world's westward motion relative to these background stars slows considerably during March. By month's end, it stands 5° east of Cancer's finest deep-sky object: the Beehive star cluster (M44).

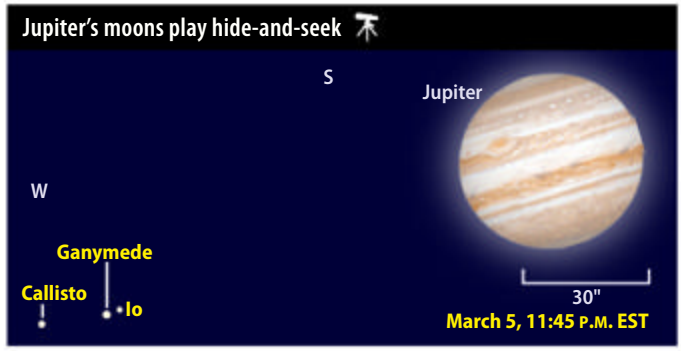
Although Jupiter looks dazzling to the naked eye, it appears truly stunning when viewed through a telescope. The best views come when it lies high in the sky during late evening. The greater altitude means the planet's light passes through less of Earth's turbulent atmosphere, providing crisp views of fine details.

Jupiter spans a robust 43" in mid-March. That's plenty big enough to reveal the planet's two equatorial belts, dark bands that run parallel to each other and sandwich a brighter zone. During moments of good seeing, when the air above you settles down and the view sharpens, you should see an alternating series of bright zones and darker belts.

Jupiter's appeal doesn't end at its cloud tops. The planet controls a family of more than 60 moons, four of which glow brightly enough to show up through any telescope. If you don't see four white dots lined up next to Jupiter, it means one or more of the moons is passing in front of or behind the giant world — events worth viewing in and of themselves.

An excellent example occurs when Ganymede emerges from Jupiter's shadow March 20. The moon starts to reappear at 10:43 P.M. EDT and takes seven minutes to return to full sunlight. Ganymede then lies one planet diameter east of Jupiter and just 3" west of Io, which serves as a convenient guide.

In addition to these run-of-the-mill satellite events (which occur every month), the moons currently are experiencing a rare series of



A riveting sequence of mutual events occurs March 5/6. Within a two-hour period starting at 11:50 P.M. EST, Io both occults and eclipses Ganymede.

COMETSEARCH

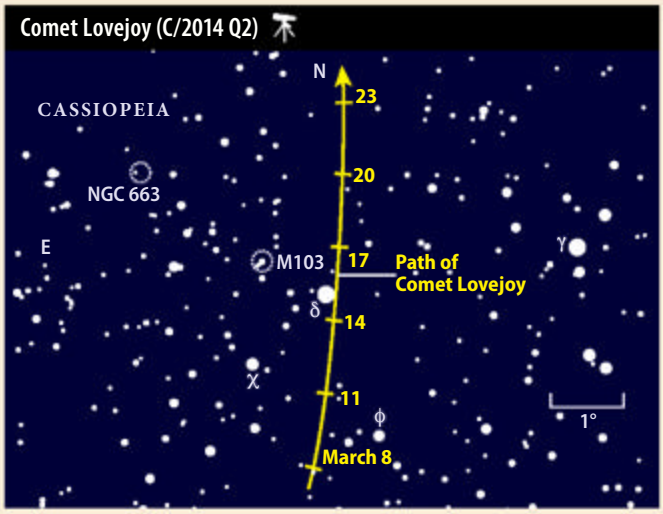
Cavorting with Cassiopeia's clusters

The fifth discovery of Australian amateur astronomer Terry Lovejoy, Comet C/2014 Q2, is now headed back to the depths of the solar system. On its outbound journey this month, it crosses the rich Milky Way background of Cassiopeia the Queen.

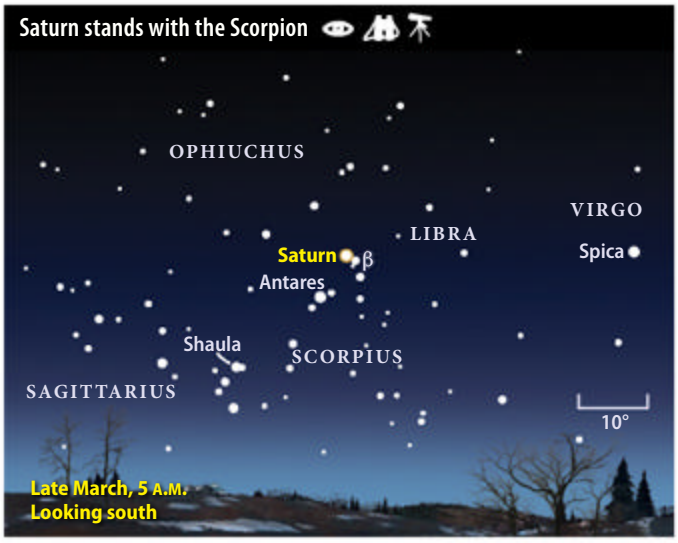
Because of its position in the far northern sky, the comet remains visible all night during March. The best observing window comes in the month's middle two weeks, however, when Lovejoy rides high in the moonless evening sky.

Comet Lovejoy has a few stellar encounters during the peak mid-March observing period. It passes 0.1° west of magnitude 2.7 Delta (δ) Cassiopeiae on the 15th, though it may be hard to spot the comet so close to the bright star's glare. Better views likely will come the next few evenings when Lovejoy slides past two 7th-magnitude open star clusters. On the 16th and 17th, it appears 1° west of M103; on the 20th, it lies 3° west of NGC 663. The comet should glow around 10th magnitude — not at all difficult to see through a 6-inch telescope and picturesque in wide-field images.

Comet observers rely on these random arrivals from the distant Oort Cloud to spice up their viewing sessions — C/2014 Q2 saved us from a couple months of really faint targets. And we need another because no currently known comets are expected to top 11th magnitude during April or May.



The northern Milky Way in Cassiopeia makes a dramatic backdrop for the passage of this 10th-magnitude visitor from the distant Oort Cloud.



Now just two months from opposition and peak visibility, the ringed planet looks stunning among the background stars of northern Scorpius.

so-called mutual events. Once every six years, Earth and the Sun pass through the plane of the satellites' orbits. Around this time, one moon may cross in front of another (an occultation) or enter another's shadow (an eclipse). North American observers can witness dozens of such events during March.

A particularly exciting sequence happens the night of March 5/6 when three moons participate in four mutual events. The action starts at 7:19 P.M. EST when Io partially occults Europa for two minutes. To observers in eastern North America, the two inner moons will appear to merge. Less than an hour later, Europa passes through Io's shadow. Europa dims noticeably at the middle of this eclipse, which lasts from 8:14 to 8:18 P.M. Half an hour after the eclipse ends, Europa disappears behind Jupiter's western limb.

Io performs a similar dance with Ganymede later that night. Viewers throughout North America can watch Io occult Ganymede beginning at 11:50 P.M. EST. At the midpoint of this eight-minute event, Io's disk appears completely inside that of the solar system's largest moon. During this occultation, Jupiter's fourth major moon, Callisto, stands nearby. Io passes less than 3" north of the outermost satellite at 12:50 A.M. EST. The night's activities wind up when Io's shadow washes over Ganymede between 1:35 and 1:46 A.M.

The "claws" of Scorpius the Scorpion grip magnitude 0.4 **Saturn** throughout March. The ringed planet spends the month within a Full Moon's width of magnitude 4.1 Nu (ν) Scorpii, the claws' northernmost star. The gas giant world rises before 1 A.M. local time March 1 and two hours earlier by the 31st.

Saturn climbs highest in the south around the break of dawn. That's the best time to target the planet through a telescope. As with Jupiter, greater altitude means sharper views. Even small scopes reveal Saturn's magnificent rings, which span 39" and tilt 25° to our line of sight in mid-March. Note in particular the dark Cassini Division that separates the outer A ring from the brighter B ring.

Any scope also will show you 8th-magnitude Titan, Saturn's largest moon. This planet-sized world orbits Saturn once every 16 days. You can find it due north of the planet March 1 and 17 and due south March 9 and 25. A handful of fainter satellites shows up through 4-inch and larger instruments. Look for 10th-magnitude Tethys, Dione, and Rhea inside Titan's orbit. Distant Iapetus, which takes 79 days to circle Saturn, also glows at 10th magnitude when it lies farthest west of the planet in early March.

The solar system's two other major planets essentially remain hidden throughout March. **Mercury** scrapes the east-southeastern horizon early in the month, appearing a mere 3° high 45 minutes before sunrise. And distant **Neptune** rises in twilight an hour before the Sun as the month closes. Both will become more conspicuous later this spring.

LOCATING**ASTEROIDS**

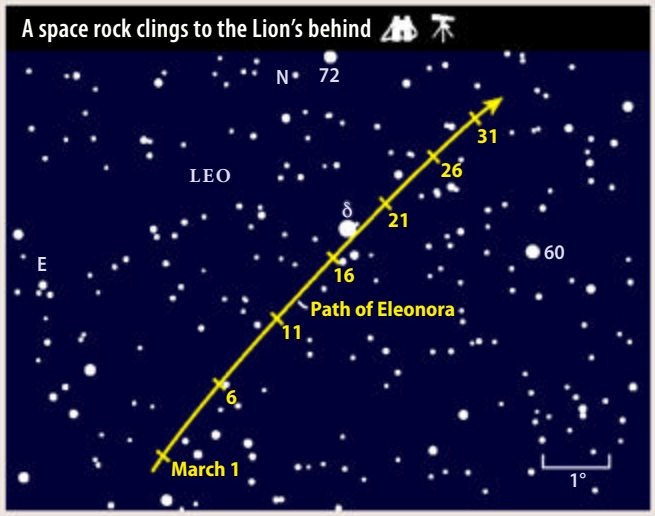
On a tailspin in Leo

Asteroid 354 Eleonora lies within a Full Moon's diameter of magnitude 2.6 Delta (δ) Leonis, the northernmost star in Leo the Lion's tail, from March 17 to 19. The proximity of the two makes it easy to spot the asteroid, and it's an opportunity you won't want to pass up. A 3-inch telescope can capture the main-belt object from the city.

But there's no guarantee. A spell of poor weather or a similarly bright background star might thwart you. Which dot in the eyepiece is the 95-mile-wide rock? Sketch the field including four or five stars, and then return to it a night or two later. The "star" that moved is Eleonora.

This high-numbered asteroid reaches opposition and peak visibility in early March, when it glows at magnitude 9.6. Luckily, Leo lies far from the Milky Way's profusion of stars. On March 20 and 21, in fact, Eleonora sits in front of a nearly blank zone dotted with only a handful of 12th-magnitude pinpricks.

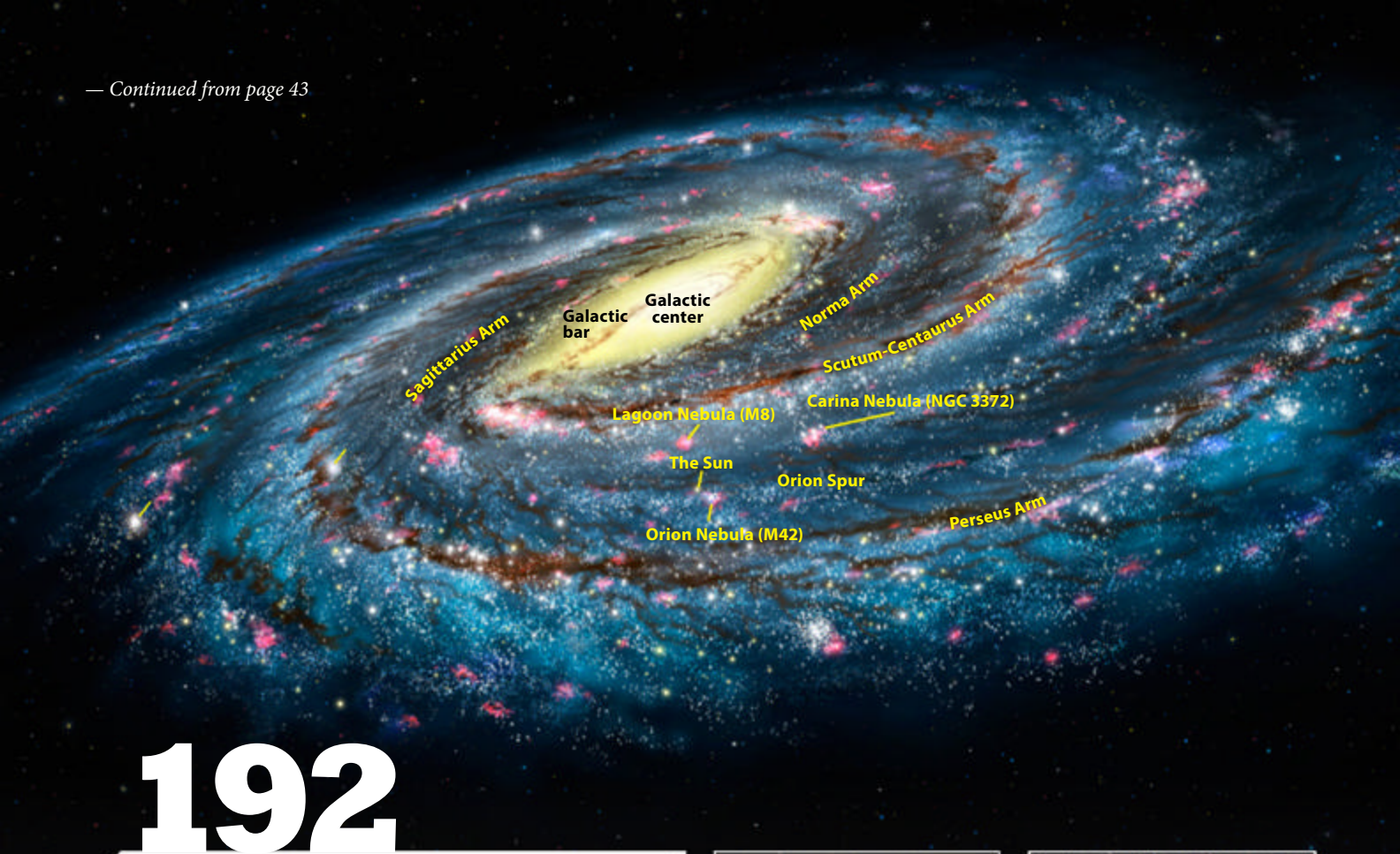
French astronomer Auguste Charlois discovered Eleonora floating among the background stars of Cancer in January 1893. It eluded discovery for so long because its orbit inclines a fair bit to the ecliptic, which often takes Eleonora well north or south of the zone where planets and most asteroids reside.



Main-belt asteroid Eleonora glows at 10th magnitude as it crosses a star-poor region in the hindquarters of Leo the Lion.

GET DAILY UPDATES ON YOUR NIGHT SKY AT **www.Astronomy.com/skythisweek.**

— Continued from page 43



192

FINDING THE MILKY WAY'S TRUE NATURE

At the beginning of the 20th century, scientists thought the Milky Way encompassed the entire universe. They also had little idea of its true shape. In 1914, American astronomer Harlow Shapley started to examine the distribution of globular clusters, conglomerations of hundreds of thousands of old stars. In particular, he studied RR Lyrae stars, a type of variable sun whose short period (typically less than one day) is related to its luminosity.

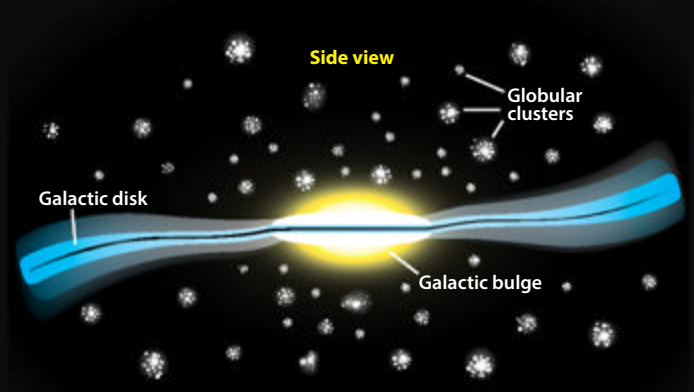
Because many RR Lyrae stars inhabit globular clusters, Shapley was able to calculate the distances to those objects. When he plotted their distribution, he found that they formed a grouping centered not on our solar system but rather on a point thousands of light-years away.

Shapley knew that his findings meant that Earth was not at the center of the Milky Way. This groundbreaking discovery — similar to the one Copernicus made when he placed the Sun at the center of our solar system — set the stage for all future studies of our stellar system.

An oblique view of our galaxy puts its structure into perspective. Two major spiral arms wind their way from the end of a central bar: the Scutum-Centaurus Arm and the Perseus Arm. Two minor arms — the Sagittarius and Norma arms — add to the galaxy's complexity. The Sun lies about 27,200 light-years from the galactic center in a partial arm called the Orion Spur. The sky's brightest nebulae stand out largely because they lie near Earth.

Astronomers think this galaxy, called the Southern Whirlpool Galaxy (M83), is what our Milky Way would look like from a similar distance, a relatively nearby 15 million light-years.

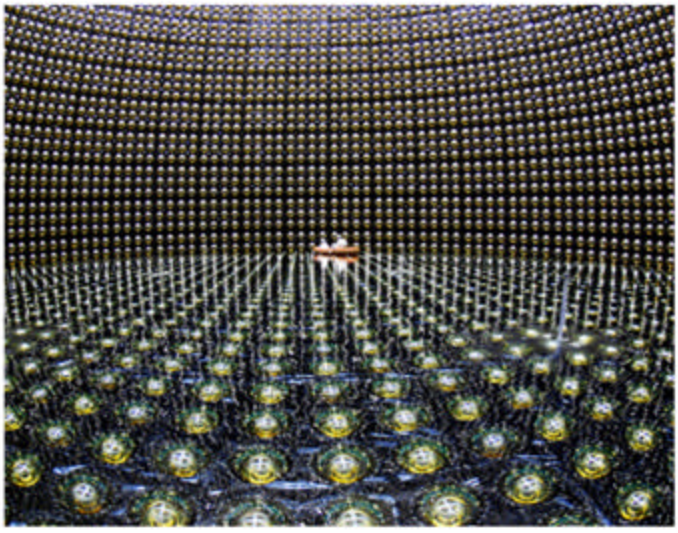
Omega Centauri (NGC 5139) is a massive globular cluster 16,000 light-years away. At 150 light-years across, it ranks as the Milky Way's largest such object and may contain some 10 million stars.



At least 158 dense balls of mostly ancient stars called globular clusters orbit the center of the Milky Way within its extended halo.

LYNETTE COOK FOR *ASTRONOMY* (TOP MILKY WAY); ADAM BLOCK/MOUNT LEMMON SKYCENTER/UNIVERSITY OF ARIZONA (M83); *ASTRONOMY*: ROEN KELLY (SIDE VIEW); TONY HALLAS (NGC 5139)

193 HIGH ENERGY



In 1956, American physicists Clyde L. Cowan and Frederick Reines discovered the neutrino — an elementary particle produced by the decay of radioactive elements. Today, various kinds of detectors exist to study these neutrally charged subatomic particles, like the one pictured here, the Super-Kamiokande in Japan.

194 Mariner 9 became the first spacecraft to orbit another planet, arriving at Mars on November 14, 1971.

195 The Stratoscope 1 and Stratoscope 2, two balloon-borne reflecting telescopes (12- and 36-inch, respectively), collected data from 1957 to 1971.

196 Danish-Irish astronomer John Louis Emil Dreyer created the *New General Catalogue of Nebulae and Clusters of Stars* (now known as the NGC) in 1888.

197 M87, the giant elliptical galaxy at the heart of the Virgo Cluster, harbors a black hole with the mass of 6 billion Suns.

198 Because air molecules scatter blue and purple light more than red and yellow light, our daytime sky is blue.

199 Of the 12 traditional constellations of the zodiac, Capricornus is the smallest.

200 SpaceX launched the first privately funded liquid-fueled rocket to reach orbit in 2008 and became the first private company to send an unmanned spacecraft to the International Space Station in 2012.

201 American astronomer Edward Emerson Barnard made the first photographic discovery of a comet October 12, 1892.

202 The Stratospheric Observatory for Infrared Astronomy is a 98-inch telescope that flies aboard a heavily modified Boeing 747SP jet.

203 Engineers used the light from Arcturus (Alpha Boötis) to trigger a photocell that turned on the lights on the first night of the 1933 World's Fair in Chicago.

204 On November 4, 2011, the International Union of Pure and Applied Physics announced element number 112 — copernicium (Cn), after Polish astronomer Nicolas Copernicus.

205 Pythagoras (c. 570–495 B.C.) was the first person known to have taught that Earth is spherical.

206 The nearly 7,500-pound Herschel Space Observatory, which operated from 2009 to 2013, was the largest infrared satellite ever launched.

207 In addition to discovering 170 gamma-ray sources from 1991 to 2000, the Compton Gamma Ray Observatory completed an all-sky map of Al-26, a radioactive isotope of aluminum.

208 A coronal mass ejection from the Sun can strip 100 to 200 tons of material from the Moon's surface as it passes our satellite.

209 Sedna, a large planetoid astronomers discovered in 2003, takes 11,400 years to complete one orbit around the Sun and can lie up to 31 times as far from our star as Neptune.

210

TAKE A LOOK

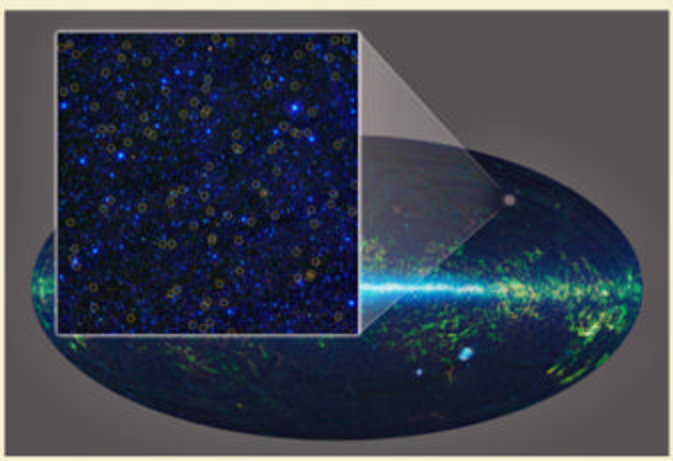
In 1608, German-Dutch spectacle-maker Hans Lipperhey invented and filed a patent for the telescope.

211 BLACK HOLE BOUNTY

In 2011, NASA's Wide-field Infrared Survey Explorer (WISE) concluded a two-year mission. Much to astronomers' delight, it identified millions of supermassive black hole candidates, objects researchers think inhabit the centers of large galaxies.

WISE scanned the whole sky twice in infrared light. Its findings have helped astronomers understand how galaxies and their supermassive black holes evolve. Some go through periodic feeding frenzies where material falls toward the black hole, heats up, and irradiates its surroundings. The largest of these monsters, up to several billion times the mass of the Sun, may even shut down a galaxy's star formation.

Astronomers used WISE to identify about 2.5 million actively feeding supermassive black holes, some of whose light has been traveling for more than 10 billion years. Previous surveys had missed about two-thirds of these objects because dust blocks their visible light. WISE easily saw these monsters because hot matter falling into the black holes warms the dust, causing it to glow in infrared light.



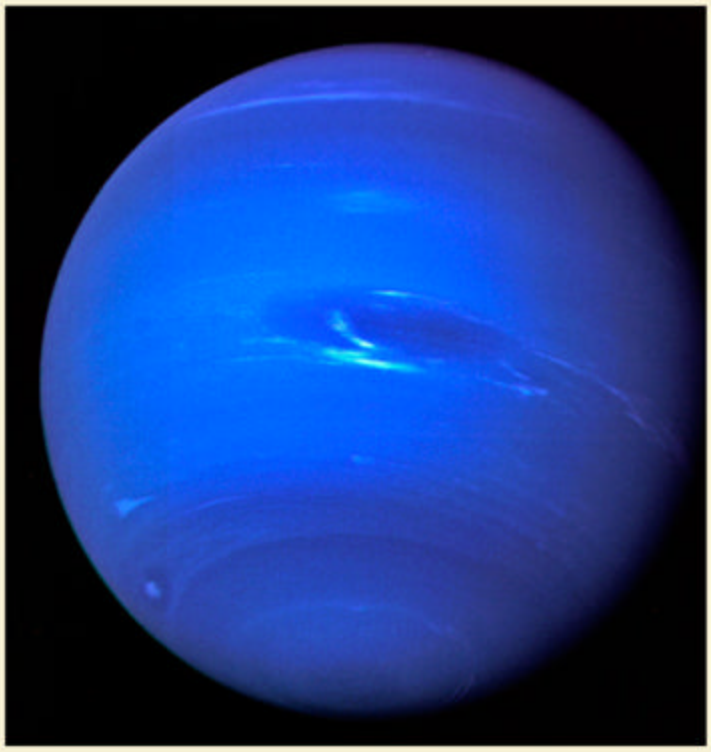
The Wide-field Infrared Survey Explorer mission's all-sky infrared survey identified millions of supermassive black hole candidates. The inset shows a region of the sky covering an area about three times the size of the Full Moon. The yellow circles identify some of the black hole candidates.

KAMIOKA OBSERVATORY/INSTITUTE FOR COSMIC RAY RESEARCH/UNIVERSITY OF TOKYO (ENERGY); COURTESY ADLER PLANETARIUM AND ASTRONOMY MUSEUM (LOOK); NASA/JPL-CALTECH/UCLA (BLACK)

212

HOT BUT FAINT

William Herschel discovered the star 40 Eridani B in 1783. Later identified as the first white dwarf, it confounded Henry Norris Russell. Its spectrum implied the heat of a large star, but it was far too dim. Astronomers now know why. The star 40 Eridani B and others pack the Sun's mass into a sphere the size of Earth. White dwarfs are the remnants of stars like ours that have aged past the red giant stage and now have cores of carbon and oxygen.



Urbain Le Verrier

John Couch Adams

Johann Gottfried Galle

213 SOLAR SYSTEM DOUBLES IN SIZE

After William Herschel discovered Uranus in 1781, astronomers compiling tables of its positions ran into a problem: The planet exhibited orbital eccentricities. That is, it wasn't where the law of gravity said it should be. Scientists gave several possible reasons for the discrepancies, but it was French astronomer Urbain Le Verrier and British astronomer John Couch Adams who theorized the existence of an eighth planet and predicted where it might be found.

Le Verrier communicated the position of the object to a number of observatories around the world. German astronomer Johann Gottfried Galle at the Berlin Observatory found it September 23, 1846, less than 1° from where Le Verrier had predicted.

214 Mars' atmosphere is 95.9 percent carbon dioxide, 2 percent argon, 1.9 percent nitrogen, 0.14 percent oxygen, and 0.06 percent carbon monoxide.

215 In 2014, the European Space Agency's Rosetta spacecraft found that Comet 67P/Churyumov-Gerasimenko was releasing the equivalent of two small glasses of water into space every second, even in a cold region 362 million miles from the Sun.

216 The Astronomical League, an overarching organization of amateur astronomy societies, was incorporated July 4, 1947.

217 In the fourth century B.C., Greek philosopher Aristotle showed Earth was a sphere by noting that our planet's shadow always appears round during lunar eclipses.

218 The first Astronomy Day, a brainchild of California amateur astronomer Doug Berger, occurred April 7, 1973.

219 The speed of light through a vacuum is exactly 299,792,458 meters per second, or 670,616,629 mph.

220 In February 2013, astronomers announced evidence for the first asymmetric supernova explosion in the Milky Way by studying supernova remnant W49B.

221 Pioneer 10, the first spacecraft to visit Jupiter, passed only 82,178 miles from the giant planet December 3, 1973.

222 In 1994, Clementine became the first spacecraft to photograph the entire Moon, finding evidence of water ice at the south polar region.

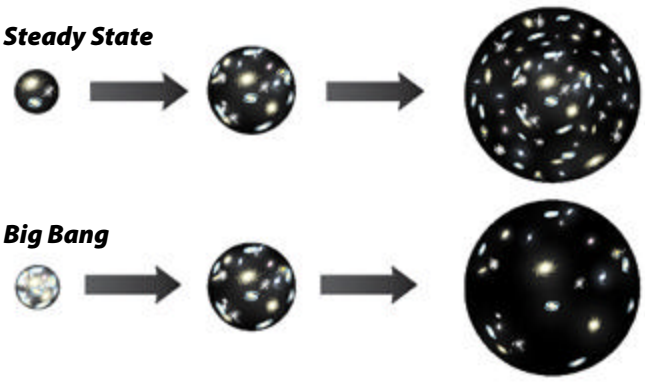
223 On February 12, 2001, NASA's Near Earth Asteroid Rendezvous-Shoemaker became the first spacecraft to land on an asteroid.

224 Astronomers took the first photograph of a star, Vega, on July 17, 1850.

225 The star R144 in the Large Magellanic Cloud's Tarantula Nebula (NGC 2070) is a binary, with components weighing up to 170 and 205 solar masses.

226 The unfortunately named SDSS J122952.66+112227.8 lies in Virgo 54 million light-years away. It shines as part of the dwarf irregular galaxy IC 3418, and it may be the farthest star astronomers have obtained a spectrum of.

227 SAME AS IT EVER WAS



In 1928, British physicist Sir James Hopwood Jeans became the first scientist to propose the steady state theory, which asserts that the universe always has appeared as it does now. The theory deals with cosmic expansion by proposing that hydrogen atoms pop into existence between galaxies but the average density of matter in the universe stays the same (top). But it does not account for the universe's 2.7-kelvin background temperature, the thermal radiation left over from the Big Bang.

229 Nuclear fusion in the Sun's core converts 600 million tons of hydrogen into 596 million tons of helium each second.

230 In 1885, Swiss physicist Johann Balmer predicted at what wavelengths hydrogen's spectral lines will appear.

231 The Moon's surface reflects only 12 percent of the light that falls on it.

232 In 2012, the Planck spacecraft measured the temperature of a 10-million-light-year-long gas filament between galaxy clusters Abell 399 and Abell 401 to be 140 million degrees Fahrenheit.

233 It wasn't until 1938 that German-American physicist Hans Bethe figured out that stars generate energy by continuously converting hydrogen into helium in their cores.

228 1.5 INCHES PER YEAR

The rate that the Moon's distance from Earth is increasing

234 Voyager 2 became the first spacecraft to fly by Uranus on January 24, 1986.

235 Voyager 2 became the first spacecraft to fly by Neptune on August 24, 1989.

236 The current rate of star formation in the universe is 3.33 percent of its peak rate.

237 The massive O-type star NGC 1624–2 has a magnetic field about 20,000 times stronger than the Sun's and nearly 10 times stronger than that of any other massive star.

238 Pioneer 11 became the first spacecraft to encounter Saturn on September 1, 1979.

239 More than half of all stars in the sky are double or other multiple systems.

240 Carl Sagan's *Cosmos: A Personal Voyage* aired the first of its 13 episodes September 28, 1980.

241 From the time of its launch from Cape Canaveral on December 2, 1995, the Solar and Heliospheric Observatory has discovered more than 2,700 comets, with an average discovery rate of one every 2.59 days.

242 NASA is currently studying the Sun and its impact on Earth through 20 different missions.

243 NASA launched 135 space shuttle flights between 1981 and 2011.

244 In 1995, astronomers Michel Mayor and Didier Queloz discovered the first exoplanet around a Sun-like star, 51 Pegasi.

245 Neptune's winds, the fastest on any planet in the solar system, blow at speeds of more than 1,300 mph.

246 In 1910, Earth passed through the tail of Halley's Comet with no effects noted despite public concerns.

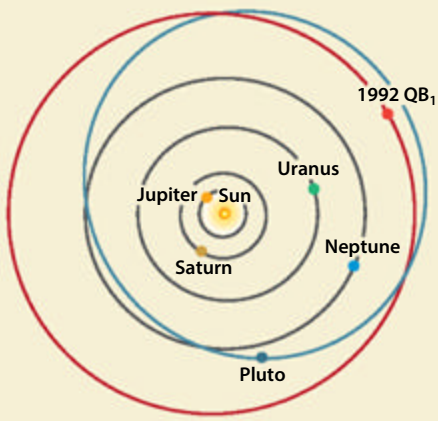
247 RING AROUND THE SUN

From the time American astronomer Clyde Tombaugh discovered Pluto in 1930, the more scientists learned about this distant world, the less it seemed to fit with the solar system's eight other planets. The first sense of possible context arrived in 1951 when Dutch astronomer Gerard Kuiper theorized that Pluto might be the brightest member of a large group of objects located some 30 to 50 astronomical units (AU; 1 AU is the average distance between the Sun and Earth) from the Sun.

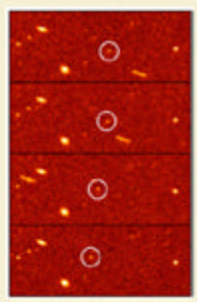
The so-called Kuiper Belt took a step closer to reality in the 1980s when computer simulations showed that most short-period comets (those that take less than 200 years to orbit the Sun) must come from a donut-shaped region in the frozen wasteland just beyond Neptune's orbit.

But Pluto remained unique until the 20th century's final decade. In mid-1992, after five years of searching, University of Hawaii astronomers David Jewitt and Jane Luu discovered a faint object in the middle of the purported Kuiper Belt. Cataloged as 1992 QB_1, the body orbits the Sun in the plane of the other planets on a nearly circular path at an average distance of 44 AU.

The object1992 QB_1 became the first recognized member of the Kuiper Belt — though astronomers now realize Pluto rightfully deserves that accolade. Four more Kuiper Belt objects turned up in the following year, and the count has since ballooned to more than 1,300. So, instead of being a misfit at the solar system's edge, Pluto truly is the tip of the solar system's iceberg.



The orbit of Kuiper Belt object 1992 QB_1 is nearly circular, in contrast to the more eccentric shape of Pluto's circuit around the Sun.



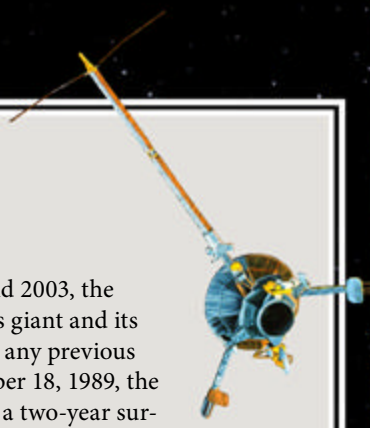
The faint dot circled in each of these images shows 1992 QB_1 — the first object identified as a member of the Kuiper Belt — moving slowly relative to the background of distant stars.

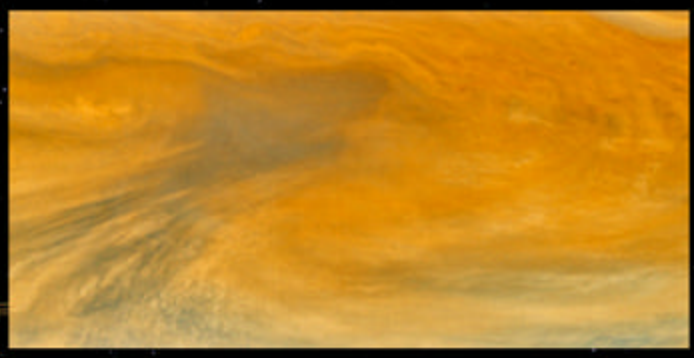
ASTRONOMY: ROEN KELLY (HOT, SAME, 1992 QB_1 ORBIT); NASA (NEPTUNE); WELLCOME LIBRARY, LONDON (LEVERRIER, ADAMS); SCIENTIFICLIB.COM (GALLE); DAVID JEWITT (UNIVERSITY OF HAWAII) (1992 QB_1 IMAGE)

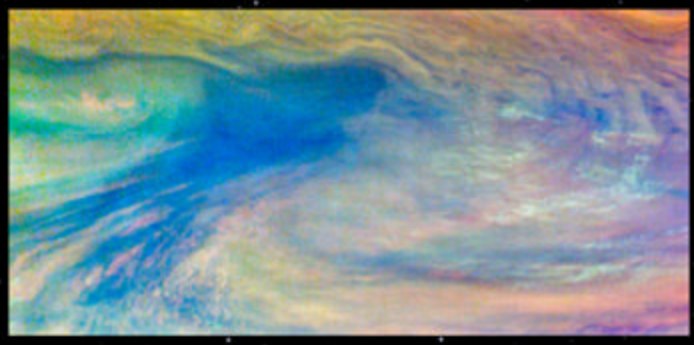
248

JOURNEY TO JUPITER

Orbiting Jupiter between 1995 and 2003, the Galileo spacecraft studied the gas giant and its many moons in more detail than any previous mission. When it launched October 18, 1989, the orbiter was expected to complete a two-year surveillance of the jovian system, but multiple extensions led to its eight years at Jupiter, returning an enormous amount of information before purposefully impacting the planet. Galileo made key discoveries about Jupiter and each of its largest moons. Even today, scientists still use its images and data to paint a better picture of these intriguing worlds.

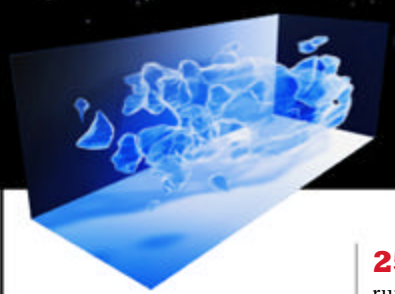






When Galileo released a probe to slice through Jupiter's atmosphere in 1995, no one expected the kind of data it would return. It appeared that the jovian atmosphere was drier and less cloudy than scientists had thought. But the truth was more complicated. Jupiter's atmosphere actually has "hot spots" with winds swirling around that clear nearby clouds and allow heat to escape, and the probe had flown directly through one. The top image shows a true-color view of such a feature, while the lower false-color image emphasizes the hot spot, which appears dark blue.

NASA (GALILEO); NASA/JPL-CALTECH (JUPITER); NASA/JPL/UNIVERSITY OF ARIZONA (IO; EUROPA; CALLISTO); NASA/JPL/DLR (GANYMEDE)



249

BLACK WIDOW

In 2007, cosmologists announced that dark matter — the mysterious mass that holds galaxies and clusters together — creates a universal web-like structure, which acts as scaffolding for normal matter. Researchers used observations from the Hubble Space Telescope and large ground-based instruments to come up with this 3-D map of dark matter's distribution.

250 The world's longest-running science program, the BBC's *The Sky at Night*, began airing episodes April 24, 1957.

251 When the universe was 14 million years old, its background temperature was 80° F, about the same as a summer day on Earth.

252 On August 28, 2003, Mars was closer to Earth than it will be for another 60,000 years.

253 As of December 15, 2014, Jupiter has 67 moons, Saturn has 62, Uranus has 27, Neptune has 14, Pluto has five, Mars has two, and Earth has one.

254 In 1862, the Chicago Astronomical Society became the first amateur astronomy club in the Western Hemisphere.

255 Astronomers believe a supermassive black hole exists at the center of every large galaxy.

256 The variable V Hydrae is a carbon star (one whose atmosphere contains carbon compounds) and is generally considered the sky's reddest star.

257 Because of absorption and re-emission (in random directions) by atoms, light from the Sun's core takes an average of 40,000 years to emerge from its surface.

258 After a 350-million-mile journey, the Curiosity rover landed on Mars on August 5, 2012, at the end of a 66-foot-long tether attached to a "sky crane" system.

259 In 1929, American astronomer Edwin Hubble discovered that the farther away a galaxy lies, the faster it recedes from Earth — meaning the universe is expanding.

260 The Sun is in a 400-light-year-wide area called the Local Bubble, where an average of 0.05 atom lies in a cubic centimeter of space — making it 10 times less dense than average for the Milky Way.

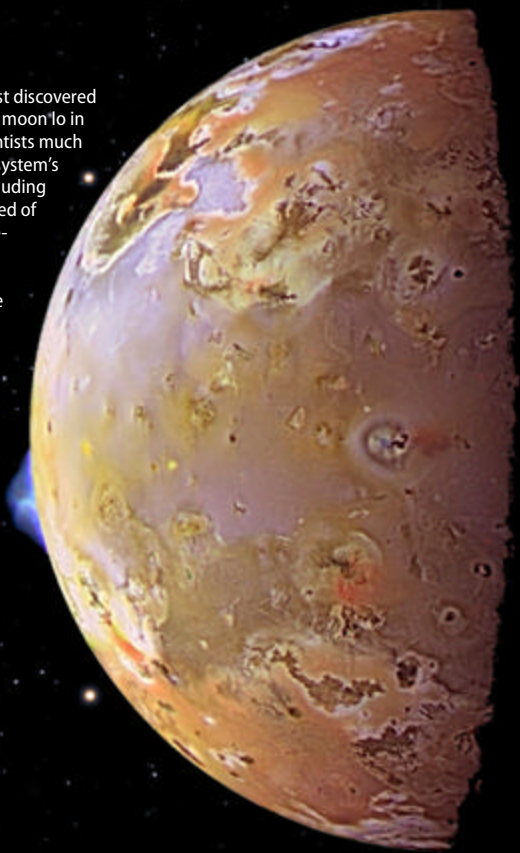
261 Scientists can detect the gravitational influence of dark matter but have not seen it, even though it makes up 85 percent of the universe's matter and 26.8 percent of its energy density.

262 Astronauts have spent more than 1,152 hours on spacewalks to help with the assembly of the International Space Station.

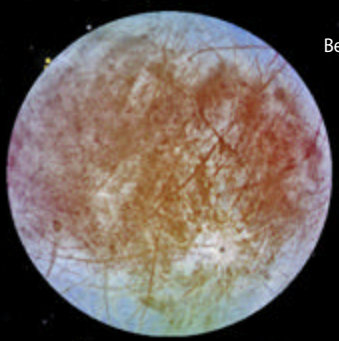
263 **66,616 mph**
Earth's average orbital speed

While making six close flybys of the largest moon in the solar system, Galileo revealed that Ganymede hosts a magnetic field independent of Jupiter's but instead embedded within it. Scientists suggest that because of the moon's molten metallic core, Ganymede's magnetic field is probably generated similarly to how Earth's is.

Callisto was considered a dead world prior to Galileo's arrival, as scientists estimated that it has the oldest surface of any solar system body. But the spacecraft revealed multiple intriguing features about the moon, including a mixing of its interior layers, a thin carbon dioxide atmosphere, and potential subsurface water.



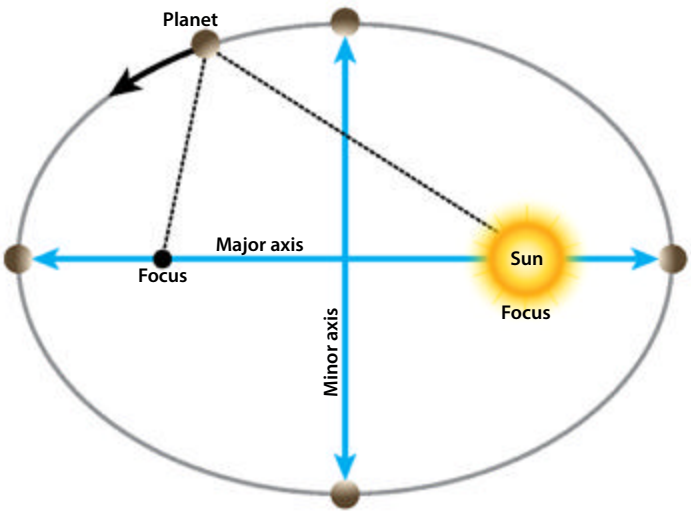
► While Voyager 1 first discovered volcanoes on Jupiter's moon Io in 1979, Galileo told scientists much more about our solar system's most active world, including that its lava is composed of material rich in magnesium, making it hotter than that found on Earth. This color image shows two volcanic plumes on Io, one on the moon's edge, visible in blue, and one near the day-night boundary, its shadow a reddish color.



Before Galileo's exploration, scientists thought of Europa as a small moon with a bright, young surface. But when the mission began studying the satellite in 1996, scientists started to find hints of a subsurface ocean that is at least 60 miles deep. The salty water survives below a thin, cracked layer of ice and occasionally reaches the surface. Because of these discoveries, Europa has become a prime target to search for microbial life in our solar system.

NASA/ESA/R. MASSEY (CALTECH) (WIDOW); *ASTRONOMY*: ROEN KELLY (STRETCH); NICHOLAUS COPERNICUS MUSEUM IN FROMBORK (SUN-CENTERED)

264 STRETCH IT A BIT



Although people sometimes say that planets "circle" the Sun, their orbits are elliptical rather than circular. The first to calculate this was German astronomer Johannes Kepler in 1609. He worked for 10 years with observations of Mars collected by Danish astronomer Tycho Brahe. Kepler finally realized that if he fit Brahe's observations to an elliptical path, he could predict where the Red Planet would be without error. Today we know that Mars' distance from the Sun varies by more than 25 million miles at different points in its elliptical orbit.

265 SUN-CENTERED SYSTEM

Nicolas Copernicus

In 1543, the landmark work *De revolutionibus orbium coelestium* by Polish astronomer Nicolas Copernicus appeared. In it, he placed the Sun at the center of our solar system with the planets — including Earth — in orbit about it. Although some early astronomers had guessed the true nature of our planetary realm, Copernicus was the first to organize his thoughts into a theory.

In the summary for this book, Copernicus put forth a number of assumptions on which he based his theory. They include: Earth's center is not the center of the universe, but only of gravity and of the lunar sphere; all the spheres revolve about the Sun as their midpoint, and therefore the Sun is the center of the universe; what appear to us as motions of the Sun arise not from its motion but from Earth's motion and the motion of our sphere, with which we revolve about the Sun like any other planet; and the apparent retrograde and direct motion of the planets arises not from their motion but from Earth's.

Not everything Copernicus wrote has proved true (like the Sun being the center of the universe). Much of what he wrote, however, was groundbreaking, and it set the stage for the advancement of astronomy in the centuries that followed.

266

EINSTEIN — RIGHT AGAIN

Albert Einstein's theories have been tested repeatedly over the past century, but the toughest to explore was his general relativity, or theory of gravity. Two predictions of the theory are that Earth warps local space-time (the geodetic effect) and also drags space-time around with it (frame-dragging effect). NASA's Gravity Probe B used four precise spherical gyros and a telescope to confirm both of these predictions in 2008, proving Einstein was right once again.

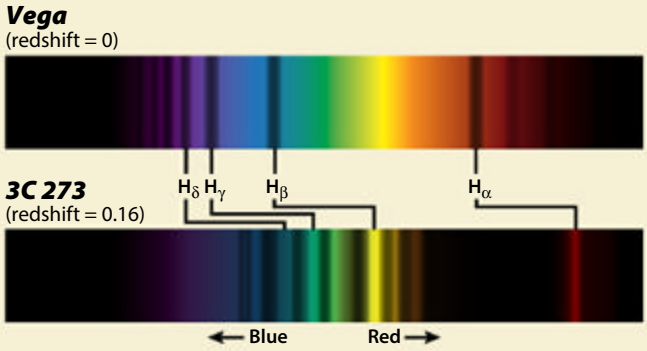
279 TOO BRIGHT, TOO FAR

The Sun is a fairly typical star. It gives off a lot of visible and infrared light, a little ultraviolet radiation, and not much else. In particular, it glows so faintly at radio wavelengths that if it truly were typical, astronomers likely never would be able to detect radio emission from any other star because of their distances.

So, you can imagine the surprise in 1960 when observers detected a starlike object that appeared bright at radio energies. The object, cataloged as 3C 48, proved to be the first of many. By 1963, astronomers had discovered three more. These "radio stars" were odd not only because they glowed brightly in the radio but also because a detailed analysis of their visible light revealed emission lines never seen before.

California Institute of Technology astronomer Maarten Schmidt solved the mystery in 1963. While examining the optical spectrum of 3C 273, at 13th magnitude the brightest of the objects, he realized that the spectral lines were those of ordinary hydrogen shifted to much longer wavelengths. The huge redshift implied that the object must lie in the distant universe, where cosmic expansion carries it rapidly away from us. Astronomers called them quasi-stellar radio sources, or quasars for short.

In the decades since, surveys have found hundreds of thousands of similar objects, and even though only about 1 percent of them emit radio waves, they all fall under the "quasar" name. Astronomers now recognize them as the cores of active galaxies that glow brightly as their supermassive black holes swallow surrounding material.



The spectrum of quasar 3C 273 features the prominent emission lines from hydrogen (labeled H_α, H_β, H_γ, and H_δ) that have been radically shifted to longer (redder) wavelengths by the expansion of the universe.

Quasar 3C 273 looks like a bright star in visible light. The squiggly line to the upper left is a jet of highly energetic particles emanating from the vicinity of the quasar's central black hole.

267 U.S. astronaut Neil Armstrong completed the first docking of two spacecraft March 16, 1966, with the Gemini Program.

268 Volcanoes resurfaced Mercury between 4 and 4.1 billion years ago.

269 A 2013 study indicated that black holes are responsible for 20 percent of the cosmic infrared background radiation.

270 Mars and Jupiter take 780 and 399 days, respectively, to move from one opposition to the next, when they appear opposite the Sun in our sky.

271 PSR 1719–14b orbits a scant 410,000 miles from its pulsar parent star, the closest known orbit for an exoplanet.

272 Every mission to Mars in the 1960s was an attempted flyby; all later flights sought either to land or orbit the Red Planet.

273 Scientists call the hypothetical white dwarfs that eventually cool to the temperature of the cosmic microwave background and become invisible "black dwarfs."

274 In 2013, the Chandra X-ray Observatory imaged a 23,000-light-year-wide cloud of 10-million-degree Fahrenheit gas that arose from an impact between NGC 1232 and a dwarf galaxy.

275 Of the 198 people who have won the Nobel Prize in physics, only two have been women.

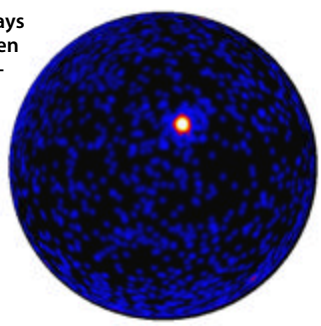
276 On October 30, 1938, Orson Welles' famous *The War of the Worlds* radio broadcast occurred, and some believed the martian attack was real.

277 On September 20, 2012, scientists announced the first detection of sugar molecules in the gas around a Sun-like star.

278 On July 11, 2013, researchers using the Hubble Space Telescope announced that the planet HD 189733b, located 63 light-years away, is "cobalt blue."

280 KA-BOOM!

On April 27, 2013, a burst of gamma rays washed over Earth unlike any ever seen before. This record-setting burst, designated GRB 130427A, produced the highest-energy light ever detected from such an event — 94 billion electron volts (some 35 billion times the energy of visible light). Gamma-ray emission lasted for several hours, setting another record. The burst originated in a dying star located roughly 3.6 billion light-years from Earth in the constellation Leo.



STANFORD UNIVERSITY (EINSTEIN); NASA/ESA/STSCI (3C 273); *ASTRONOMY*; ROEN KELLY (SPECTRUM); NASA/DOE/FERMI LAT COLLABORATION (KA-BOOM)

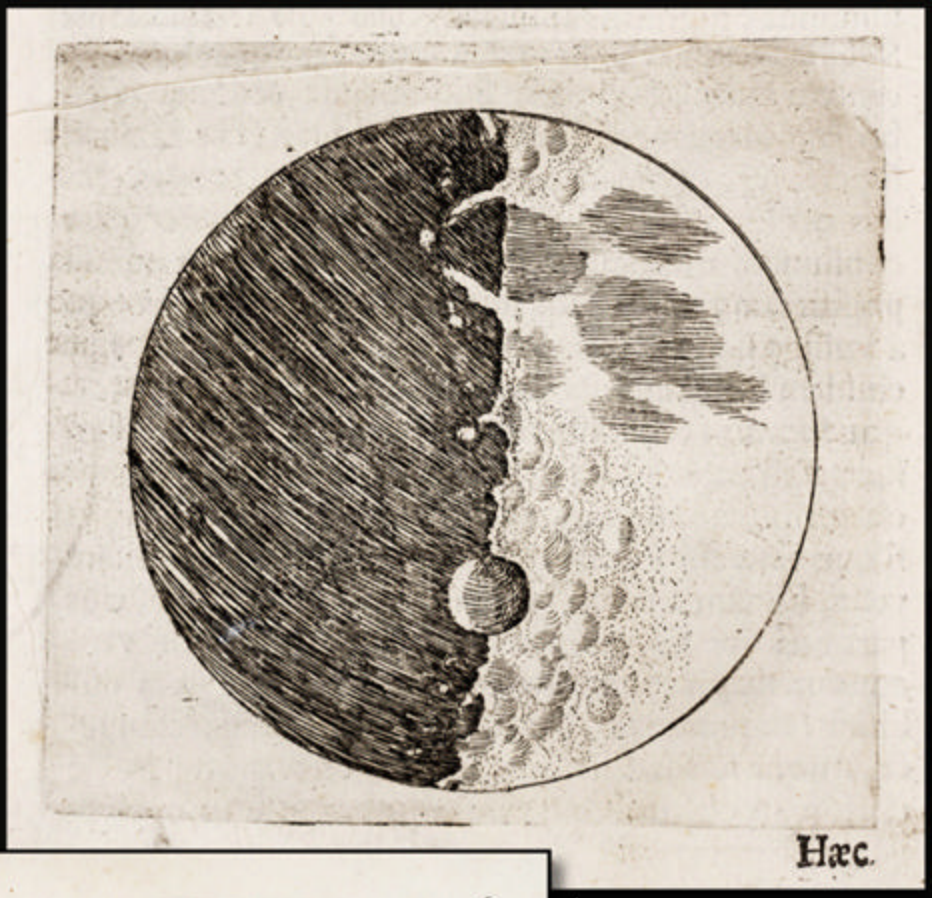
281

GALILEO'S DISCOVERIES

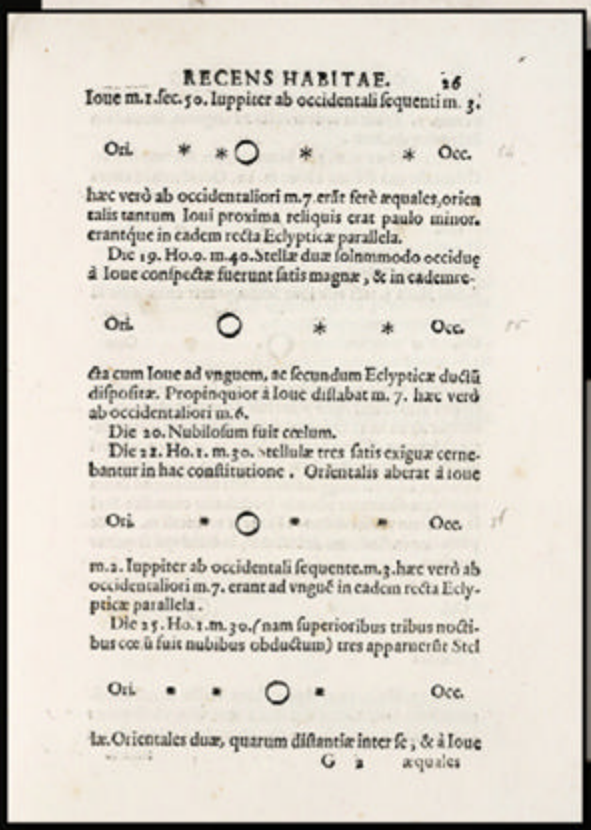
Many people mistakenly believe that Italian scientist Galileo Galilei invented the telescope. He didn't. That said, Galileo was the first to use the telescope to extensively study celestial objects. In doing so, he made several spectacular discoveries and challenged the accepted knowledge of the previous 2,000 years.

In his *Sidereus Nuncius* ("The Sidereal Messenger"), published in March 1610, Galileo noted irregularities on the surfaces of the Sun (sunspots) and the Moon (craters and mountains), both "heavenly" objects that most learned individuals of the time thought were perfect. He saw that Venus went through phases similar to the Moon. He spied stars too faint for the naked eye to perceive. And perhaps most importantly, he saw that four satellites orbited Jupiter. This observation proved that not all celestial objects orbited Earth, the prevalent thought at the start of the 17th century.

Indeed, Galileo not only began the era of telescopic astronomy, he set the standard of scientific inquiry for centuries to come.



▲ With an improved telescope of 30 power, Galileo saw the Moon as a rough world full of large craters, tall mountains, and smooth, dark "seas."


RECENS HABITAE. 16

Ioue m.1.sec.50. Iuppiter ab occidentali sequenti m. 3.

Ori. * *○ * * Occ.

hæc verò ab occidentaliori m.7. erãt ferè æquales, orien talis tantum Ioui proxima reliquis erat paulo minor. erantque in eadem recta Eclypticæ parallela.

Die 19. Ho.0. m.40. Stellæ duæ solummodo occidue à Ioue conspectæ fuerunt satis magnæ, & in eadem re-

Ori. ○ * * Occ.

cta cum Ioue ad vnguem, ac secundum Eclypticæ ductũ dispositæ. Propinquior à Ioue distabat m. 7. hæc verò ab occidentaliori m.6.

Die 20. Nubilosum fuit cœlum.

Die 22. Ho.1. m.30. Stellulæ tres satis exiguæ cernebantur in hac constitutione. Orientalis aberat à Ioue

Ori. * ○ * * Occ.

m.2. Iuppiter ab occidentali sequente m.3. hæc verò ab occidentaliori m.7. erant ad vnguẽ in eadem recta Eclypticæ parallela.

Die 25. Ho.1. m.30. (nam superioribus tribus noctibus cœ ũ fuit nubibus obductum) tres apparuerũt Stel

Ori. * * ○ * Occ.

læ. Orientales duæ, quarum distantiæ inter se; & à Ioue

G 2 æquales

◄ Jupiter's moons appear as asterisks in Galileo's initial drawings. The Italian scientist discovered Io, Europa, and Callisto on January 7, 1610, and Ganymede six days later.


SIDEREVS NVNCIVS

GALILEO GALILEO PATRITIO FLORENTINO

PERSPICILLI

MEDICEA SIDERA

LINDA HALL LIBRARY OF SCIENCE, ENGINEERING, & TECHNOLOGY (ALL *SIDEREUS NUNCIUS* IMAGES); SCIENCE MUSEUM PICTORIAL (GALILEO)

282
RADIO GA GA

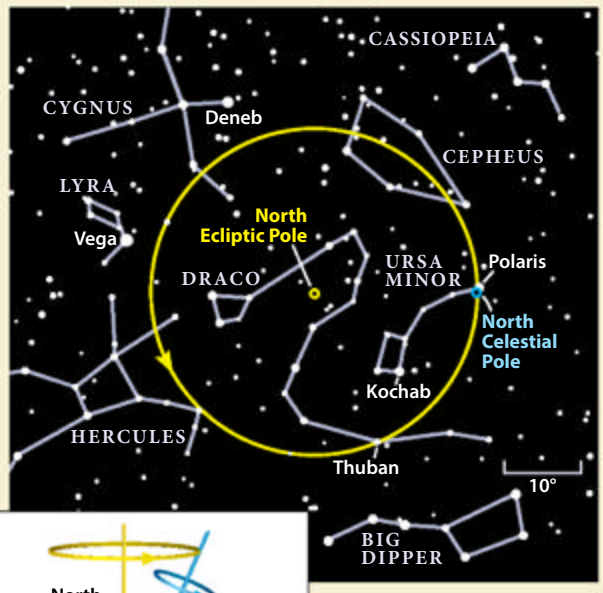
American amateur radio astronomer Grote Reber completed the first sky survey of radio sources in 1941 with a 31.4-foot parabolic radio telescope he built in his backyard in Wheaton, Illinois.

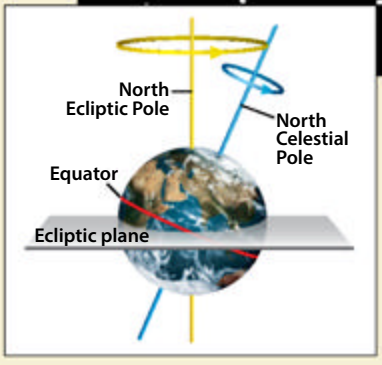
283 SLOW CHANGE

In 127 B.C., Greek philosopher Hipparchus, who lived in Nicaea, was creating a star catalog (in which, by the way, he developed the magnitude system). He noticed that when he compared the positions of certain stars (in particular Regulus in Leo and Spica in Virgo) to those in previous catalogs, the stars had moved relative to the position of the September equinox. He developed a theory in which the equinoxes — not the stars — were moving (precessing) through the sky.

Earth orbits the Sun, spins on its axis once a day, and exhibits other motions as well — one of which is precession. You can see an example of precession every time you spin a top. As the top begins to slow, it also starts to wobble on its axis.

A gyroscope does the same thing, and so does Earth. As a result, a line extending upward from Earth's North Pole slowly traces a large circle around the sky centered on the pole of the ecliptic (the plane of Earth's orbit around the Sun).

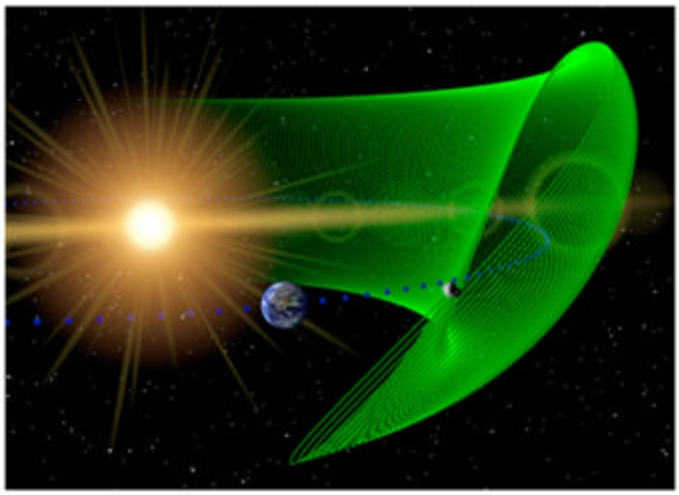




Earth's spin axis precesses and traces out a circle over about 26,000 years. The brightest star nearest the North Celestial Pole is the "North Star." Because the axis points in a different direction over time, the identity of the North Star also changes.

285 The densest galaxy known, M60–UCD1, has a stellar density 15,000 times greater than found in the Sun's neighborhood.

284 DELICATE DANCE



In October 2010, a team of NASA scientists using the Wide-field Infrared Survey Explorer announced they had discovered the first asteroid that shares Earth's orbit. 2010 TK_7 has a diameter of approximately 1,000 feet, an orbital inclination of 21°, and a tadpole-shaped looping path. It precedes our planet in its orbit around the Sun by 60°, oscillating around the fourth Sun-Earth Lagrangian point. It never gets closer to Earth than about 12.4 million miles.

286 According to the traditional horoscope, the Sun spends either 30 or 31 days in each "sign" of the zodiac. In reality, it spends 45 days in Virgo, 38 days in Pisces, and only seven days in Scorpius.

287 On average, Jupiter takes four days to travel a distance equal to the width of the Full Moon.

288 On average, Pluto takes 130 days to travel a distance equal to the width of the Full Moon.

289 The Andromeda Galaxy (M31) contains more than 300 billion stars, and the galaxy's total mass may exceed 1 trillion Suns.

290 Some 1.4 million glass photographic plates of sky objects taken at major observatories still exist.

291 In 1957, Margaret and Geoffrey Burbidge, William Fowler, and Fred Hoyle described how nearly all the elements in the universe (except for primordial hydrogen and the helium and lithium produced in the first minutes after the Big Bang) were produced either by fusion in the cores of stars or during the supernova explosions of massive stars.

292 By the end of 2014, astronomers had tallied 314 periodic comets, 89 non-periodic comets, and more than 1,600 Kreutz sungrazers.

293 The coldest brown dwarf, WISE J085510.83–071442.5, has a temperature between –55° and 8° Fahrenheit.

294 On July 31, 2018, Mars will lie 35.78 million miles from Earth, its closest until it approaches to 35.36 million miles September 11, 2035.

295 Neptune completed its first post-discovery orbit June 8, 2011.

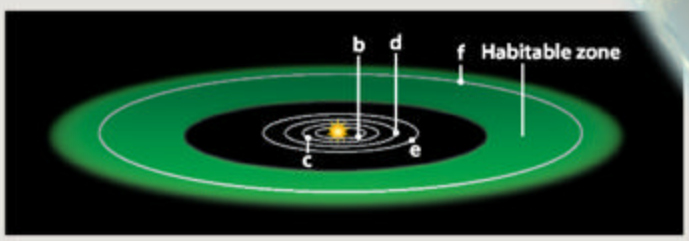
296 The most massive white dwarf found to date is GD 518 in Draco, with a mass 1.2 times that of the Sun.

NRAO (RADIO); *ASTRONOMY*: ROEN KELLY (SLOW); NASA/JPL-CALTECH/UCLA (DANCE)

297

EARTH 2.0?

The Kepler space telescope accomplished a primary goal nearly a year after a crippling wheel failure when scientists announced that they had uncovered an Earth-sized planet in the habitable zone of its parent star. Such a location means the planet would have the right temperature to host liquid surface water, a key ingredient for life as we know it. Designated Kepler-186f, the exoplanet lies about 500 light-years away in the constellation Cygnus and orbits in 130 Earth days a red dwarf star half the size and mass of the Sun. The entire Kepler-186 system consists of five known worlds.

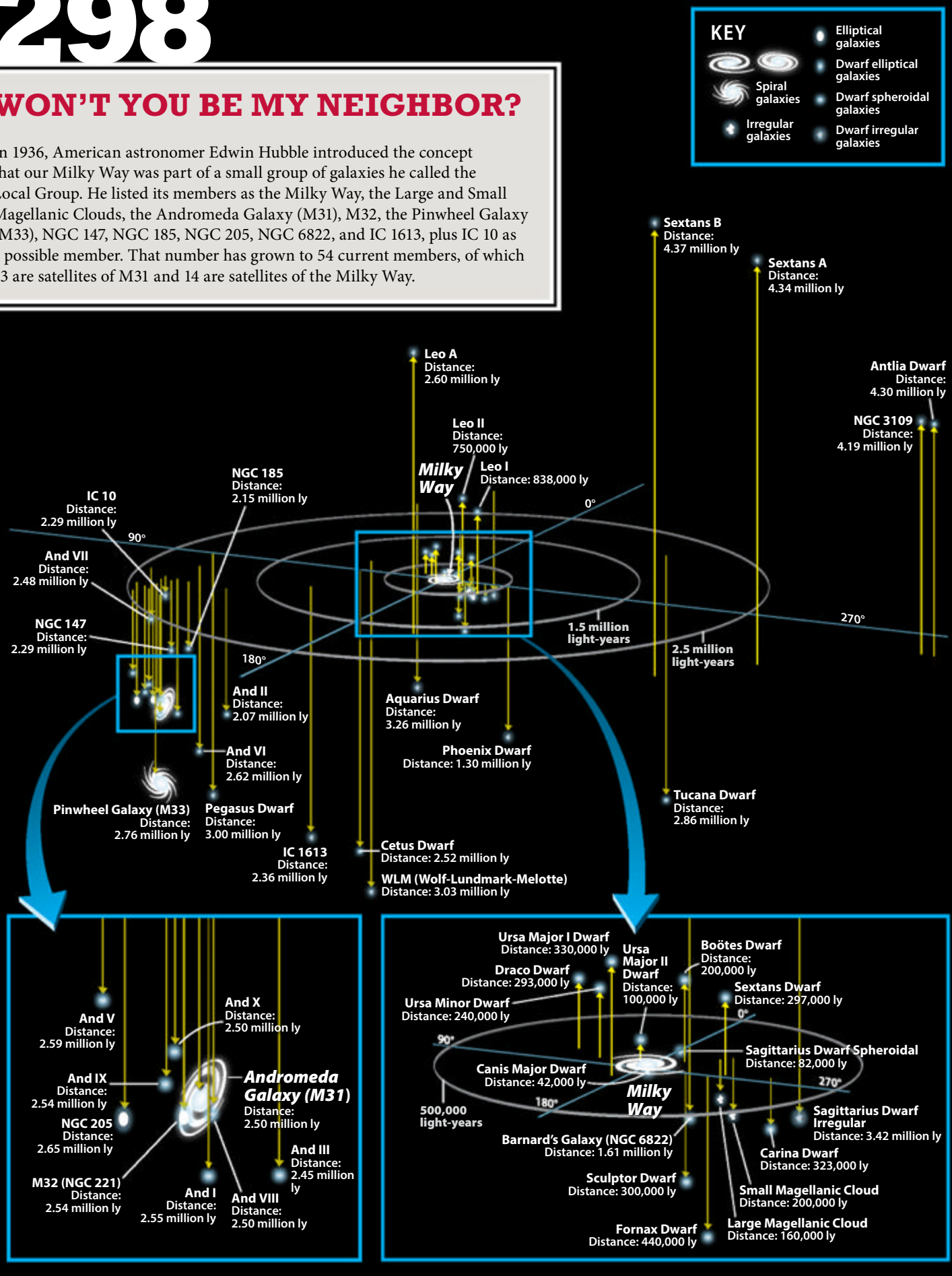


NASA AMES/SETI INSTITUTE/JPL-CALTECH (KEPLER-186F); *ASTRONOMY*: ROEN KELLY, AFTER NASA (DIAGRAM)

298

WON'T YOU BE MY NEIGHBOR?

In 1936, American astronomer Edwin Hubble introduced the concept that our Milky Way was part of a small group of galaxies he called the Local Group. He listed its members as the Milky Way, the Large and Small Magellanic Clouds, the Andromeda Galaxy (M31), M32, the Pinwheel Galaxy (M33), NGC 147, NGC 185, NGC 205, NGC 6822, and IC 1613, plus IC 10 as a possible member. That number has grown to 54 current members, of which 33 are satellites of M31 and 14 are satellites of the Milky Way.



299 During the past two millennia, 70 comets have reached the subjective category of "great."

300 Fullerene (C_{70}), which contains 70 carbon atoms, is the largest molecule found in space.

301 Mercury is most brilliant when on the far side of the Sun from Earth.

302 Our North Star, Polaris (Alpha Ursae Minoris), ranks as the sky's 48th-brightest star.

303 Iron melts at 10,800° F at Earth's core-mantle boundary.

304 Recent studies have calculated that one-fifth of Sun-like stars harbor Earth-sized planets in their habitable zones.

305 The Valles Marineris canyon on Mars stretches nearly 2,500 miles, almost long enough to cross the continental U.S.

306 Earth's core produces just a millionth of a percent as much energy as a brown dwarf.

307 The star Tau Boötis' magnetic field flips once a year, 11 times more often than the Sun's.

308 By observing Halley's Comet in 1531, German humanist Peter Apian was the first to demonstrate that a comet's ion tail always points away from the Sun.

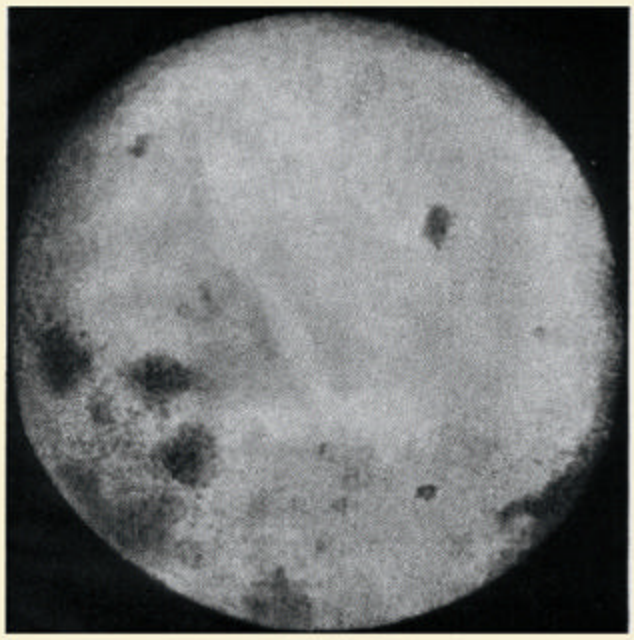
309 Brown dwarfs have temperatures below 3,300° F, radii less than 8.7 percent of our Sun, and luminosities under 1/8,000 of the Sun.

310 The minor planet 87 Sylvia was the first triple asteroid system discovered.

311 As of December 15, 2014, astronomers had discovered more than 11,000 near-Earth asteroids.

312 On average, total solar eclipses occur once every 360 years for any location on Earth.

313 The sky's brightest nighttime star, Sirius (Alpha Canis Majoris), outshines its companion star, Sirius B, by 9,500 times.



NASA/GSFC (SEA, BIG BANG)

320 SEA CHANGE

Throughout history, no one knew what the Moon's farside looked like. Locked in a gravitational embrace with Earth, our satellite rotates on its axis with the same period as it revolves around our home world. Astronomers suspected that the hidden hemisphere would appear similar to the one we see, with maria — vast basins filled with frozen lava — covering approximately 30 percent of the surface and the rest dominated by heavily cratered highlands.

Humanity's first view of farside terrain came from the Soviet Union's Luna 3 spacecraft. The probe looped around the Moon on October 7, 1959, snapping 29 photographs that covered about 70 percent of the farside. As the spacecraft headed back toward Earth, it managed to transmit 17 of those photos before ground controllers lost contact.

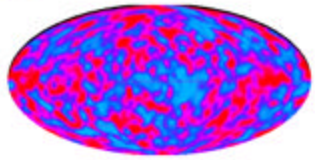
Despite the noisy, low-resolution nature of the images, they revealed a world totally different from the nearside. Craters cover nearly the entire surface, with only two small maria — Ingenii and Moscoviense — breaking up the rough topography. This image shows Mare Moscoviense as a dark patch at upper right. The small, dark circle directly below it is the crater Tsiolkovskiy, and Mare Ingenii lies to its right on the image's edge. From this viewpoint, the nearside makes up approximately one-quarter of the lunar disk on the left. Mare Marginis and Mare Smythii, which sit on the border between the nearside and farside, are the two larger dark areas to the lower left of center.

In the 55 years since Luna 3 revealed the Moon's backside, scientists have learned that the lunar crust in this hemisphere is roughly twice as thick as on the nearside. Although researchers are not sure why this dichotomy exists, the farside's thicker crust would have made it more difficult for lava to seep to the surface and fill in existing basins.

314 If the Milky Way were the size of a single tennis ball, the Andromeda Galaxy (M31) would lie 5.6 feet away.

315 The star SMSS J031300.36–670839.3 has fewer heavy elements than any other star found yet, including 12 million times less iron than our Sun.

316 Scientists studying NASA's Mars Reconnaissance Orbiter data discovered a 150-foot-wide crater that formed March 27/28, 2012.



321 BIG BANG CONFIRMED!

NASA launched the Cosmic Background Explorer in November 1989. During its four-year mission, the spacecraft confirmed that the cosmic microwave background (CMB) — the Big Bang's relic radiation — glows at a temperature of 2.73 kelvins. It also discovered seeds of structure in the CMB (seen in this all-sky map as tiny temperature fluctuations in red [hotter] and blue [cooler]) that grew into the galaxies and galaxy clusters we see today.

317 It takes the Sun 2.13 minutes to rise at Earth's equator, but only 10.15, 5.92, 4.78, and 2.85 seconds to do so at Jupiter, Saturn, Uranus, and Neptune, respectively.

318 The age of the core of a zircon crystal, 4.374±0.006 billion years, confirms that the oldest known continental crust on Earth formed shortly after the Moon.

319 A stellar-mass black hole is approximately 1 quadrillion times as dense as water.

322

CREATIVE DESTRUCTION

In 1054, Chinese astronomers noted a "guest star" bright enough to see in daylight for several weeks and at night for two years. It remained a historical footnote until the 18th century, when telescopic observers discovered a glowing gas cloud near the spot in the constellation Taurus. The shape of the object on a sketch made in 1844 by William Parsons, the Third Earl of Rosse, gave it its common name, the Crab Nebula.

But its importance didn't come to light until the 20th century, when astronomers realized that the nebula's gaseous tendrils are expanding. By tracing the movement back in time, scientists associated the nebula with the Chinese guest star.

Soon after, researchers tied the Crab to a type of exploding star called a "supernova," which often originates when a massive star exhausts its nuclear fuel and collapses. Theory suggested that such explosions should leave behind a compact remnant composed almost entirely of neutrons.

The Crab helped tie all these pieces together in 1968 when astronomers discovered a rapidly rotating neutron star, or "pulsar," at the nebula's center. This object spins 30 times a second and provides the energy needed to keep its gaseous envelope glowing.

NASA/ESA/J. HESTER AND A. LOLL (ARIZONA STATE UNIVERSITY)

323 STARLESS SYSTEMS

Models of our universe predict the existence of gas-rich but starless galaxies in the early cosmos, which would have fed future galaxies to become the communities of hundreds of billions of stars we see today. In 2012, astronomers at the European Southern Observatory announced they might have spotted some 100 of these dark galaxies in this image by searching for those illuminated by nearby ultraviolet light from a bright active galaxy.

324 During its 13-month mission in 2010 and 2011, NASA's NEOWISE discovered about 34,000 new solar system bodies, including 18 comets.

325 The earliest known supernova is SN 185, spotted in the present-day constellation Circinus the Compasses in A.D. 185 by Chinese astronomers.

326 Moons orbit some 200 asteroids.

327 The asteroid-like object 10199 Chariklo is the largest centaur, a class of objects with unstable orbits in the region of the giant planets.

338 GUEST STAR

Ancient humans were enamored with the night sky and keenly aware of its motions. There was little else to watch. Their petroglyphs are thought to record constellations as well as comets and eclipses. And if a starlike bright light suddenly pierced the blue sky and stayed visible for weeks or more, it too likely would have been a major event in the lives of our ancestors. That's true for the supernova of 1054 in Taurus. Chinese astronomers recorded it as a "guest star," and in the American Southwest, it's thought that the Ancestral Puebloans captured the supernova on cliff walls near Chaco Canyon, shown here, a site with many astronomical ties.

328 Because the Moon keeps the same face toward Earth, it must rotate once for each orbit it makes.

329 Astronomers discovered the first asteroidal moon in 1993 orbiting 243 Ida.

330 According to a study released March 10, 2014, Earth lies 27,200±520 light-years from the Milky Way's core.

331 At a distance of 42,000 light-years, the Canis Major Dwarf irregular galaxy is the nearest galaxy to Earth.

332 The tiniest red dwarf stars contain only 8 percent of the Sun's mass but will survive for approximately 11 trillion years.

333 The Giant Magellan Telescope, which will take its first observations in 2021, has a construction budget of $1.05 billion.

334 In 2012, astronomers discovered that a cloud of hot, thin gas with a mass between 10 billion and 60 billion times that of the Sun surrounds our Milky Way.

335 The Sun's shape deviates from that of a perfect sphere by 17 parts in 1,000,000.

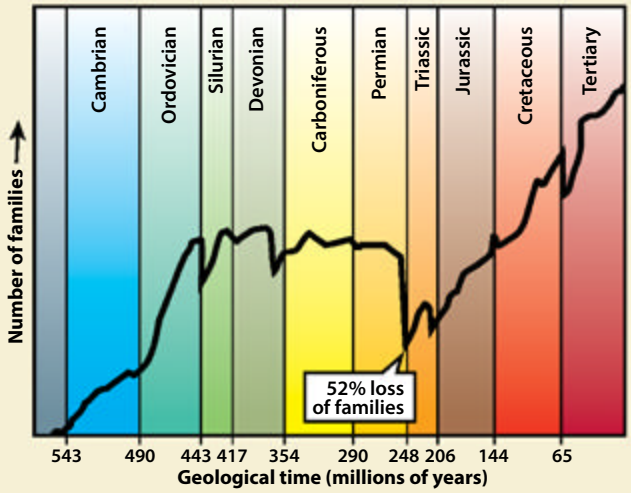
336 For star formation to occur in a molecular cloud, the density must be at least 5,000 hydrogen molecules per cubic centimeter.

337 The first star atlas charting both hemispheres was Johann Bayer's *Uranometria*, in 1603.

339 WORSE THAN THE DINOSAURS

Some 250 million years ago, an estimated 75 percent of all land-living species and up to 95 percent of all ocean-dwelling species disappeared forever. This mass extinction may have taken as little as 10,000 years.

The event at the end of the Permian geological period — still a mystery to scientists to this day — was the worst Earth has ever endured. It was far more devastating than the better-known extinction 65 million years ago that ended the dinosaur era. Imagine that 95 out of every 100 people you know suddenly died. The Great Dying, as some call the Late Permian extinction, was the biggest population crash in evolutionary history.



Five times in Earth's history, mass extinctions pruned the tree of life. The Late Cretaceous extinction took the dinosaurs, but a far more severe die-off occurred in the Late Permian Period.

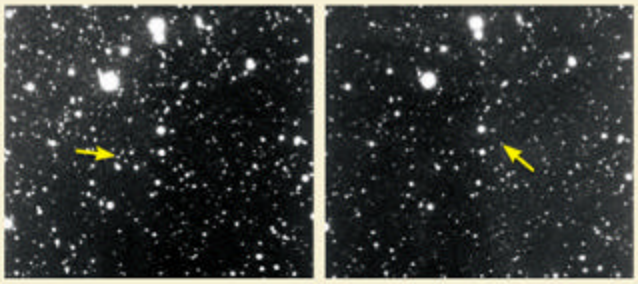
ESO (STARLESS); VINCENT MURPHY VIA FLICKR (GUEST STAR); *ASTRONOMY*: JAY SMITH, ORIGINAL DATA BY DAVID RAUP AND RICHARD SEPKOWSKI (WORSE)

340

HOT FOOT

William Herschel used dark glass when he looked through telescopes at the Sun. And he had noticed that, depending on which color he used, the light gave him different sensations of heat. In 1800, he devised a simple experiment: Light that passes through a prism divides into colors, and he measured each with a thermometer that he compared to two experimental controls. Red was clearly hottest, but what was more, as he placed the thermometer beyond that color, the temperature actually increased. Herschel had discovered infrared radiation. It was the first demonstration that there was light beyond what's visible to the human eye. Two centuries later, astronomy is booming with discoveries made on both Earth and from space that would be impossible without the expanded reaches of the light spectrum.

M31 IMAGE: INFRARED: ESA/HERSCHEL/PACS/SPIRE/J. FRITZ (U. GENT); X-RAY: ESA/XMM-NEWTON/EPIC/W. PIETSCH (MPE)



Clydge Tombaugh compared these two photographs he took January 23 and 29, 1930, and found that a small dot of light had moved in the same direction predicted for Planet X (arrow).

341 A PLANET FOR 76 YEARS

Clyde Tombaugh

In 1929, Lowell Observatory in Flagstaff, Arizona, hired 23-year-old Clyde William Tombaugh to search for Planet X, the name given to a world that astronomers theorized lay beyond the orbit of Neptune. On February 18, 1930, Tombaugh found an object whose position had changed on two previous photographic exposures. The observatory announced the discovery of what would become Pluto on March 13.

348 In the 1930s, astronomers Walter Baade and Fritz Zwicky proposed that the gravitational collapse of a massive star could trigger a huge explosion, which Zwicky called a supernova.

349 Earth's axis currently tilts 23.4374458° to the plane of its orbit around the Sun.

350 The Sun's outer corona extends 12 solar radii from the star's surface.

351 Sunrise on Earth lasts an average of 2.13 minutes, while the same event on Mercury takes 16.13 hours.

352 A person who weighs 200 pounds at Earth's poles would weigh 199 pounds at the equator, mainly due to centrifugal force.

353 Venus has the slowest rotation of any planet in the solar system, only 4 mph.

362 THE GOD PARTICLE

On July 4, 2012, physicists working at CERN's Large Hadron Collider (pictured) announced their discovery of an elementary particle crucial to the standard model of particle physics, confirming it as the Higgs boson March 14, 2013.

342 Mintaka (Delta Orionis) is the nearest bright star to the celestial equator, meaning it crosses the sky in nearly a straight line.

343 The MErcury, Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft completed its 3,000th orbit of the innermost planet April 21, 2014.

344 Two supermassive black holes lie just 120 times the Earth-Sun distance from each other at the center of galaxy SDSS J120136.02+300305.5.

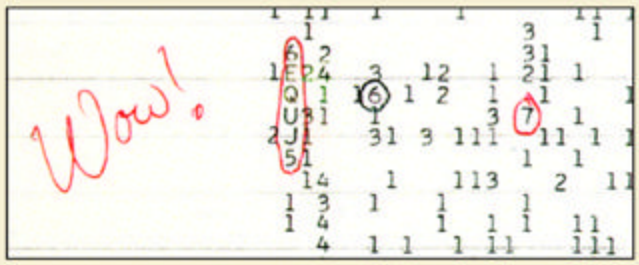
345 Jupiter's Great Red Spot has shrunk from a size of 25,500 miles across in the 1800s to 10,250 miles across as of May 2014.

346 The closest hypervelocity star known lies 42,000 light-years from Earth and is speeding away from the galaxy's center at 296 miles per second.

347 Earth continuously gives off 44 trillion watts of energy, about half of it generated by the radioactive decay of substances like uranium and thorium in the deep interior.

360 13 BILLION YEARS

The age of the oldest known exoplanet, PSR B1620–26 b



361 WOW!

On August 15, 1977, American radio astronomer Jerry R. Ehman identified a signal received by Ohio State University's Big Ear radio telescope in Delaware, Ohio. At the time, Ehman was working on a project searching for extraterrestrial life. The signal lasted 72 seconds (the maximum length the telescope could observe it) and originated from a region of sky 2.5° south of Chi Sagittarii. It has never been seen again.

Researchers gave two values for the signal's frequency: 1420.356 megahertz and 1420.4556 MHz. These values are about 0.0498 MHz below and above the specific frequency (1420.40575177 MHz) of the radiation given off when neutral hydrogen atoms change energy states (the radiation has a wavelength of 21 centimeters). Because this radiation is so prevalent throughout the universe, some astronomers believe other civilizations might use it to transmit interstellar communications.

354 Each year the Sun evaporates approximately 100,000 cubic miles of water from Earth, which then falls mainly as rain.

355 The observable universe has a diameter of 93 billion light-years.

356 Asteroid 2005 YU_{55} passed 201,700 miles from Earth on November 8, 2011, the closest approach by a large space rock in the 21st century.

357 The air on Mars is 100 times thinner than the air on Earth.

358 It would take nine years to walk to the Moon.

359 Driving a car to the nearest star at 70 mph would take more than 356 billion years.

LOWELL OBSERVATORY (PLUTO, TOMBAUGH); OHIO STATE UNIVERSITY RADIO OBSERVATORY/NAAPO (WOW!); MAXIMILIEN BRICE/CERN (GOD)

363 WHERE'S THE REST OF ME?

While studying the motions of galaxies in the vast Coma Cluster in 1933, Swiss astronomer Fritz Zwicky discovered that there is more to the universe than meets the eye. He measured the speeds of many individual galaxies and then calculated how much mass would be required to generate the gravitational pull needed to bind them into a cluster. He found that the cluster's luminous matter provided nowhere near enough mass to contain the rapidly moving galaxies and concluded that large quantities of invisible material, which he called "dark matter," must be present.

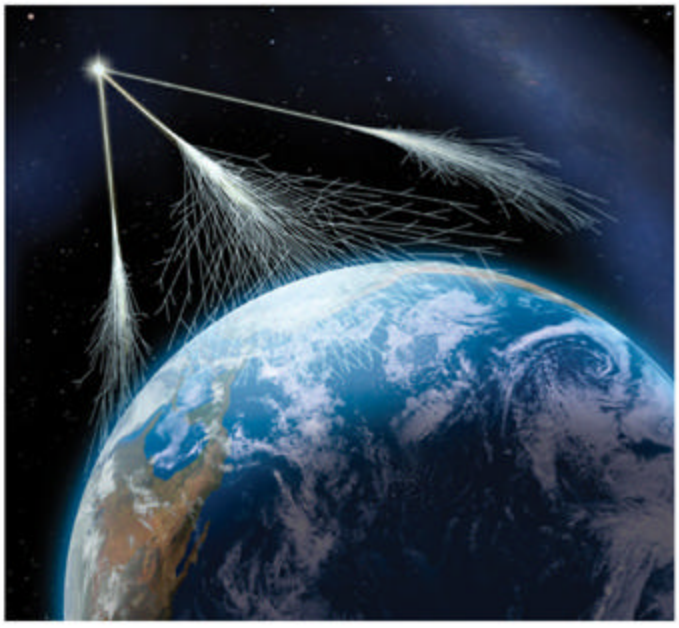
The Coma Cluster served as a great laboratory for Zwicky's research. The cluster lies in the constellation Coma Berenices, which places it about as far from the gas and dust of the Milky Way's disk as possible. The collection contains thousands of galaxies spread across a sphere more than 20 million light-years across. And at a distance of some 300 million light-years, it has an angular diameter several times that of the Full Moon. (The Hubble Space Telescope image seen here covers only a tiny fraction of its extent.)

The mystery over dark matter has only deepened in the 80 years since Zwicky's discovery. Observations show this material makes up 27 percent of the mass-energy content of the universe, more than five times what normal matter contributes. And astronomers now know that it is the glue that holds not only clusters together but also individual galaxies.

364 1.23 MILLION MPH

The speed required to escape the Milky Way's gravitational grasp

366 THE POWER COSMIC



In 1911 and 1912, Austrian-American physicist Victor Franz Hess repeatedly took three highly accurate radiation detectors to altitudes of up to 17,400 feet. He found radiation levels at that altitude four times as strong as on the ground and concluded that the radiation originated in space. We now know these "cosmic rays" are almost all high-energy protons and heavier atomic nuclei that come from energetic objects in space, like active galaxies and the remnants of exploded stars. They can produce showers of lower-energy particles and light when they collide with molecules in Earth's atmosphere.

367 Nychthemeron is a period of 24 consecutive hours, sometimes used as a more technical definition of "day."

368 The Sun, once thought of as an average star, is more massive than 80 percent of the stars in the universe.

369 The nearest star that could become a type Ia supernova is the white dwarf IK Pegasi B, which lies some 150 light-years away.

370 Each second, approximately 100 trillion neutrinos pass through your body.

365 EINSTEIN WARPS SPACE

Albert Einstein published his landmark general theory of relativity in 1915. To most scientists, it was an elegant if esoteric remake of Isaac Newton's theory of gravity, treating this fundamental force as a manifestation of space-time curvature. Matter warps space, and whenever an object encounters that distortion, its path is deflected. The idea holds whether the object is a planet orbiting a star or a light photon passing near a massive body.

Back in 1915, there were few ways to test general relativity. The theory explained the intricacies of Mercury's orbit better than Newton's could, but most of relativity's effects were too subtle for scientists to measure at the time. One idea held promise, however. The Sun has far more mass than any other object in the solar system, so it should warp space enough to deflect a light beam passing nearby. Measure the position of a star near the Sun's limb, or edge, and it should be shifted slightly from its normal spot.

Scientists launched expeditions to view the May 1919 total solar eclipse and photograph stars near the Sun's limb during totality. They then compared these photos with ones of the same star field taken at night (when the Sun, obviously, wasn't nearby). British astronomer Arthur Eddington, who led an expedition to the island of Príncipe off Africa's west coast to view the eclipse, captured this image showing two stars (at the center of the two dashed lines) next to the Sun's limb. His analysis showed that the shift matched that predicted by Einstein and far exceeded what Newton's gravity could explain. The discovery cemented relativity's place in science and Einstein's place in the public's mind.

371 Some brown dwarfs are so dim that at the Sun's distance, they would be fainter than the Moon.

372 From a dark site, you can see six meteors per hour on an average non-shower night.

373 The most distant stars in the Milky Way are red giants lying about 780,000 and 890,000 light-years away, putting them in the far reaches of our galaxy's halo.

374 A run-of-the-mill black hole has a diameter of 18 miles.

375 The Curiosity rover recorded its highest temperature on Mars, 45° F, September 28, 2012.

376 Kepler-16b was the first system where astronomers found a planet orbiting two stars, like Tatooine in the sci-fi epic *Star Wars*.

377 The star R136a1 in the Large Magellanic Cloud is the most massive (265 solar masses) and most luminous (8.7 million times brighter than the Sun) star known.

378 The earliest certain observation of Halley's Comet dates to 240 B.C., as recorded by the Chinese text *Shih chi* ("Records of the Grand Historian").

379 If you compressed Earth's mass so it formed a black hole, its diameter would be ⅔ inch.

380 In 1796, French astronomer and mathematician Pierre-Simon Laplace developed the still accepted hypothesis that the solar system's planets condensed out of a dust-rich nebula surrounding the embryonic Sun.

381 Blazars — active galaxies with high-speed jets of material pointed toward our telescopes — emit as much energy in one second as the Sun does in 317,000 years.

382 Jupiter's moon Amalthea is reddish because sulfurous volcanic material blasted into space by another jovian moon, Io, falls onto its surface.

393 MOVIN' RIGHT ALONG

A great debate was emerging in astronomy when the young Vesto Slipher arrived in Flagstaff, Arizona, in 1901 to take up work at the fledgling Lowell Observatory. At stake was the very existence of the cosmos. Is our Milky Way the entire universe, or could the mysterious spiral nebulae actually be "island universes" as well? Slipher wanted to find out, but observations would be difficult because the spectra of the nebulae were strangely faint. By observing the outer planets, he had become proficient at using a hulking early spectrograph strapped to the back of the 24-inch Clark Telescope (shown above) to break apart that faint light into its individual color components. Blue implies an approaching object and red one that's moving away. So, in 1912, he turned the instrument on the Andromeda Nebula (M31) and measured it moving closer at an unprecedented rate — presumably too fast to be in the confines of the Milky Way. Slipher's observations of 14 other "nebulae" would show all but three were redshifted, giving the first evidence for the expanding universe.

383 The least massive dwarf galaxy scientists have found so far is Segue 2, which clocks in at just a thousand stars with a ball of dark matter holding them together.

384 Libra's stars used to be part of the constellation Scorpius.

385 Saturn's moon Titan likely harbors a salty ocean below a 30-mile-thick ice shell.

386 The signals received on Earth from the 20-watt transmitter aboard the Galileo spacecraft at Jupiter were 1 billion times weaker than a transistor radio heard from a distance of 3,000 miles.

387 Since forming, our Milky Way Galaxy has rotated some 60 times.

388 The brightest satellite (not counting the Moon) is Ganymede, which shines at magnitude 4.4 when Jupiter is closest to Earth.

394 DARK NIGHT

In 1826, German astronomer Heinrich Olbers famously wondered why the night sky is dark. In an infinite unchanging universe, every line of sight would end at a star's surface, making each point in the sky that bright. Astronomers resolved the paradox in the 20th century when they realized the universe is finite and expanding.

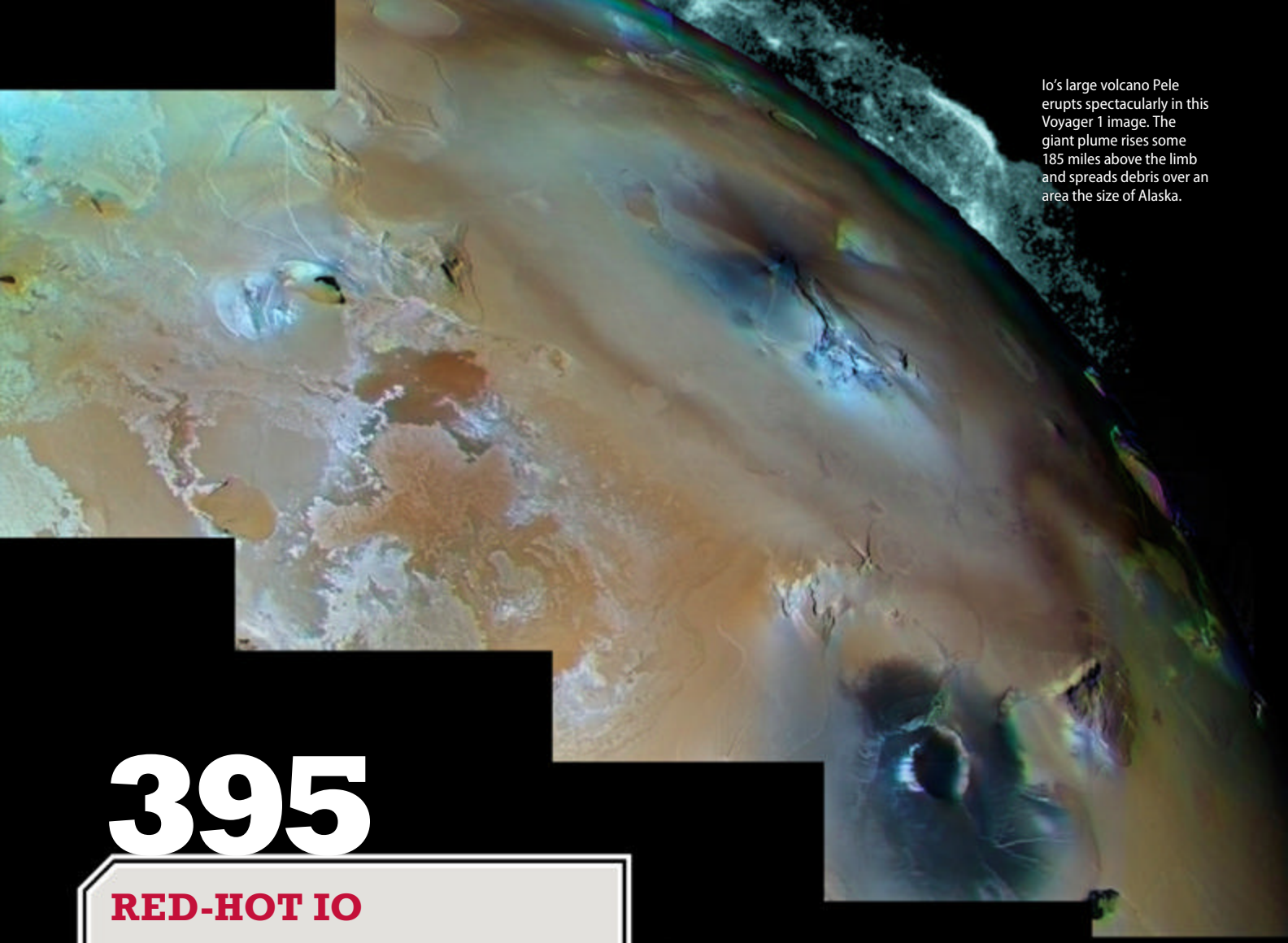
389 In October 2011, researchers announced they had found enough water in the planet-forming disk around the star TW Hydrae to fill thousands of Earth oceans.

390 The combined gravity of two small moons, Pandora and Prometheus, keep Saturn's F ring in place.

391 If you weigh 200 pounds on Earth, you would weigh 33 pounds on the Moon.

392 The Greek philosopher Aristotle (384–322 B.C.) suggested that comets were exhalations that rose from Earth into the atmosphere, where they ignited.

NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA) (REST); ARTHUR EDDINGTON (EINSTEIN); *ASTRONOMY*: ROEN KELLY (COSMIC, NIGHT); KEVIN SCHINDLER/LOWELL OBSERVATORY (MOVIN')



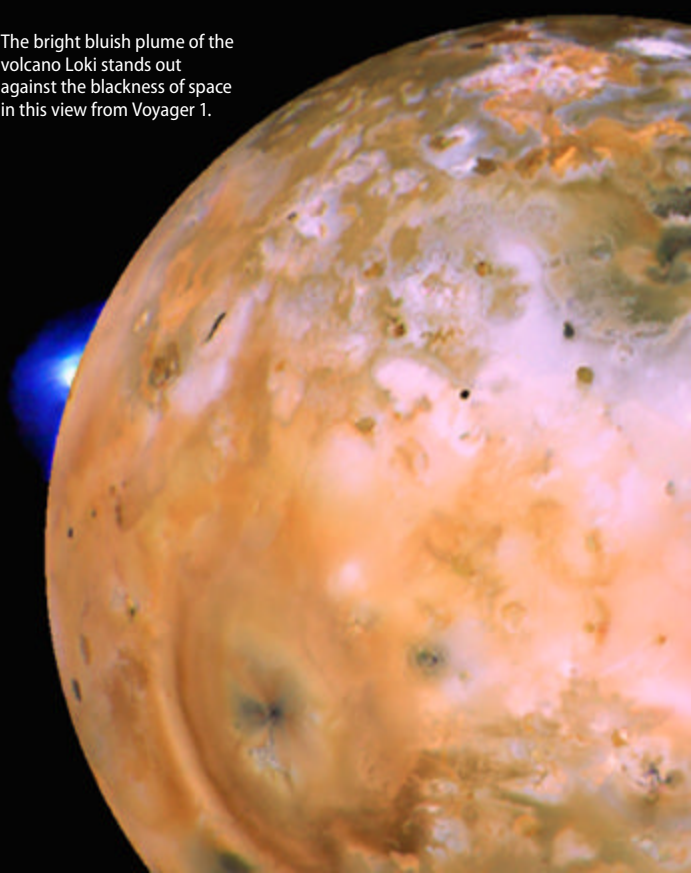
Io's large volcano Pele erupts spectacularly in this Voyager 1 image. The giant plume rises some 185 miles above the limb and spreads debris over an area the size of Alaska.

395

RED-HOT IO

When the Voyager 1 spacecraft approached Jupiter in March 1979, planetary scientists expected the planet's four large moons to be intriguing subjects worthy of significant observing time. But innermost Io delivered beyond almost anyone's dreams. Images revealed nine erupting volcanoes, each dwarfing anything ever seen on Earth. Umbrella-shaped plumes reached heights up to 185 miles and spread deposits over an area more than 620 miles across.

In the 35 years since, scientists have detected more than 160 volcanoes on Io's surface that spew enough material to coat the moon in a layer 4 inches thick every year. The heat for these eruptions comes from tidal flexing induced by Jupiter's massive gravity and the subtle but significant pulls of the neighboring moons Europa and Ganymede. It's an idea that took almost everyone by surprise — except for University of California, Santa Barbara, scientist Stanton Peale and his colleagues, who published the idea just three days before Voyager 1 arrived.



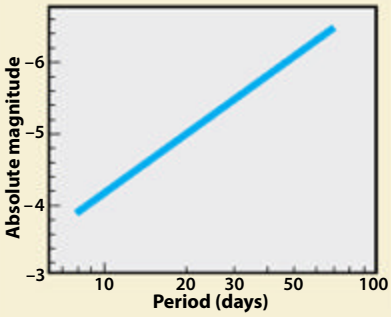
The bright bluish plume of the volcano Loki stands out against the blackness of space in this view from Voyager 1.

NASA/JPL/USGS

396

BLACK HOLE BACKGROUND

Prior to NASA's Chandra X-ray Observatory, observations in these tiny wavelengths had turned up a uniformly glowing background. When astronomers started using the spacecraft for long-duration deep-field surveys in 1999, they resolved the X-rays into a plethora of individual extragalactic sources powered by supermassive black holes — quasars — and other active galactic nuclei, like this Chandra image of Hercules A.



The period-luminosity relationship for Cepheid variables expresses the fact that the longer it takes one of these stars to complete a cycle, the greater its luminosity (typically expressed as absolute magnitude).

Henrietta Leavitt discovered the period-luminosity relationship by observing 25 Cepheid variable stars in the Small Magellanic Cloud.

397 TICK, TOCK

You might not want to set your watch by the rhythmic pulsations of a Cepheid variable star, but you could use them to set the scale of the cosmos. English astronomer John Goodricke climbed the first rung of this distance ladder in 1784 when he noticed that the star Delta Cephei varied from magnitude 3.6 to 4.3 and back again in a period of 5.366 days. Over the years, observers discovered a host of other stars showing similar patterns of variation, though the periods ranged from a couple of days up to more than 100 days. They became known as Cepheid variables, after the prototype in the constellation Cepheus.

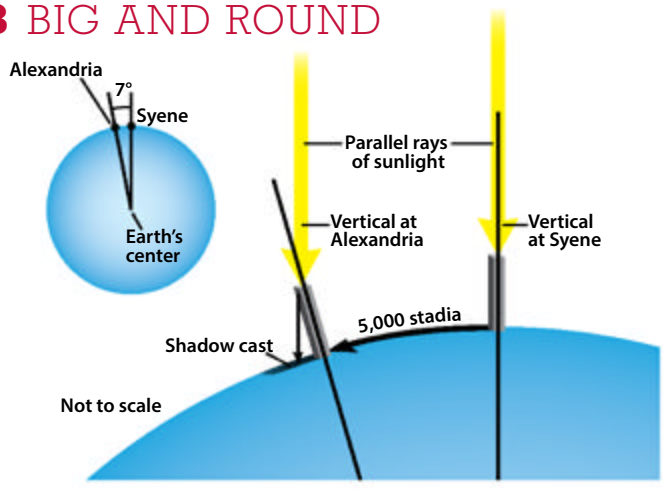
The big breakthrough came in 1912 when American astronomer Henrietta Leavitt climbed the second rung of the distance ladder. She discovered 25 Cepheids in the Small Magellanic Cloud (SMC), one of the Milky Way's satellite galaxies. Although no one knew at the time that the SMC is a separate galaxy, scientists understood that all of its stars lie at essentially the same distance from Earth.

Leavitt found that the brighter a Cepheid appears, the longer it takes to go from maximum light to minimum light and back. Once astronomers calibrated this so-called period-luminosity relationship through observations of a few nearby Cepheids, they could calculate the distance to any of these stars. They simply had to measure the star's period and compare the observed brightness with the intrinsic brightness derived from the relationship.

Just as important, Cepheids are luminous, so astronomers can observe them millions of light-years away. The period-luminosity relationship proved to be the distance ladder's crucial rung, setting the scale for finding distances throughout the cosmos.

398 BIG AND ROUND

Greek astronomer Eratosthenes (c. 276–195 B.C.) made the first accurate measurement of Earth's size. He knew that at noon on the summer solstice, the Sun appeared directly overhead at Syene, Egypt (modern-day Aswan), but was about 7° from the zenith at Alexandria some 5,000 "stadia" due north. He realized that the difference reflected the curvature of Earth's surface, and simple math let him calculate our planet's circumference. Although researchers don't know which of the various Greek stadia Eratosthenes used, most scientists think he was in the right ballpark.



399 Mars has no north star because its axis points toward a nondescript part of the sky roughly midway between Deneb (Alpha Cygni) and Alderamin (Alpha Cephei).

400 The only person whose ashes are on the Moon is planetary scientist Eugene Shoemaker.

401 The Sun's current density is 1,408 kg/m^3, but it will evolve into a white dwarf with a density of 1 billion kg/m^3.

402 The observable universe contains approximately 2.4 quinvigintillion (10^{80}) atoms.

403 Light from solar flares takes eight minutes to reach Earth, while the material from solar ejections takes days.

404 On Pluto, light from the Sun is 300 times as bright as light from a Full Moon on Earth.

405 In one nanosecond, light travels approximately 1 foot.

406 Venus has more than three times the land area of Earth.

407 On average, the Milky Way's star formation rate is one solar mass per year.

408 As of November 3, 2014, 215 individuals had made the trip to the International Space Station.

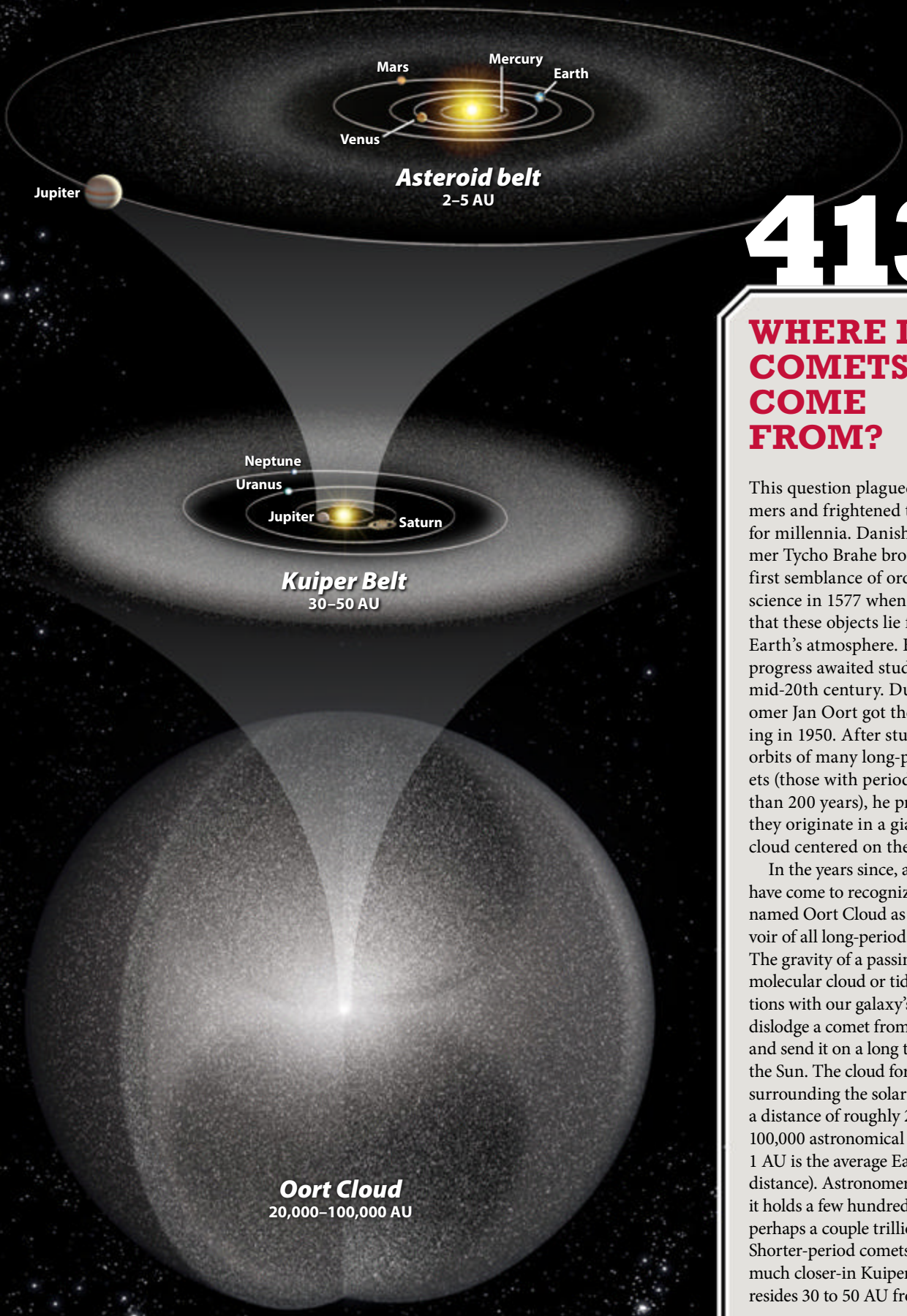
409 Saturn's north pole points only 6° away from where Earth's North Pole points.

410 Between 10 and 40 tons of meteoric dust enter Earth's atmosphere each day.

411 Uranus' orbital plane tilts less than 0.8° from Earth's orbit — the closest match in the solar system.

412 Because of tidal forces between Earth and the Moon, our day is getting longer by 1.4 milliseconds each century.

X-RAY: NASA/CXC/SAO, OPTICAL: NASA/STScI, RADIO: NSF/AUI/NRAO/VLA (BLACK); *ASTRONOMY*: ROEN KELLY (PERIOD-LUMINOSITY RELATIONSHIP BIG); HARVARD COLLEGE OBSERVATORY (LEAVITT)



413

WHERE DO COMETS COME FROM?

This question plagued astronomers and frightened the masses for millennia. Danish astronomer Tycho Brahe brought the first semblance of order to comet science in 1577 when he showed that these objects lie far beyond Earth's atmosphere. But real progress awaited studies in the mid-20th century. Dutch astronomer Jan Oort got the ball rolling in 1950. After studying the orbits of many long-period comets (those with periods greater than 200 years), he proposed that they originate in a giant spherical cloud centered on the Sun.

In the years since, astronomers have come to recognize the aptly named Oort Cloud as the reservoir of all long-period comets. The gravity of a passing star or molecular cloud or tidal interactions with our galaxy's disk can dislodge a comet from its home and send it on a long trek toward the Sun. The cloud forms a sphere surrounding the solar system at a distance of roughly 20,000 to 100,000 astronomical units (AU; 1 AU is the average Earth-Sun distance). Astronomers estimate it holds a few hundred billion to perhaps a couple trillion comets. Shorter-period comets arise in the much closer-in Kuiper Belt, which resides 30 to 50 AU from the Sun.

ASTRONOMY: ROEN KELLY

Gemmy yellow sulfur

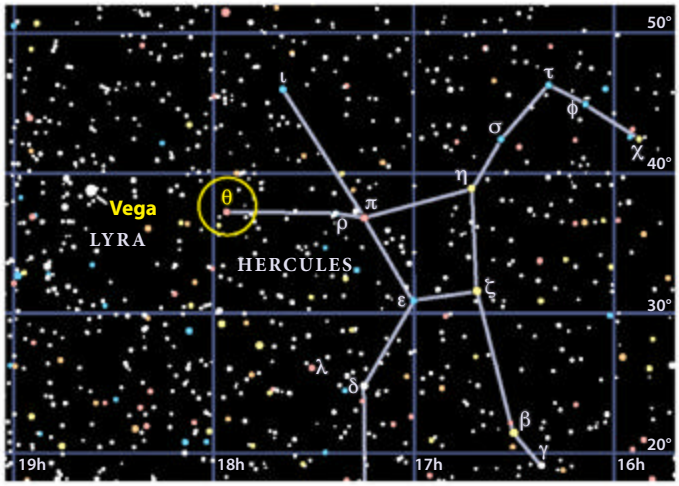
Purple tanzanite

414 INHALE, EXHALE

Around 2.4 billion years ago, the Great Oxygenation Event (GOE) altered the air surrounding our planet from a primordial methane-rich atmosphere into the oxygen-rich one we breathe today. The driving force behind this change was cyanobacteria, single-celled life with the ability to photosynthesize. These microscopic creatures took in carbon dioxide and gave out oxygen.

The oxygen that life produced before the GOE was combining with iron in the rocks rather than building up in the atmosphere. Then, around 2.4 billion years ago, no more unoxidized iron was left in Earth's crust. The result — a runaway buildup of oxygen in the atmosphere — changed our planet forever. The gas was then free to combine with existing minerals, and the result was a tripling of mineral types, like those above.

415 WHERE ARE WE GOING?



In 1783, English astronomer William Herschel looked at more than a dozen stars to see how they moved across the sky perpendicular to our line of sight. By analyzing these so-called proper motions, he determined that the Sun and its attendant planets are moving toward a point in the constellation Hercules called the "solar apex." Herschel was pretty close. Astronomers now know that we are heading toward a spot some 3° south of the 4th-magnitude star Theta (θ) Herculis (circled), which itself is 8° west of brilliant Vega.

416 Light from the edge of the Sun takes more than two seconds longer to reach us than light from the center of its surface.

417 The satellite with the largest orbital period in the solar system is Saturn's moon Fornjot, at 1,491 Earth days.

418 Because of geometry, the longest possible duration of the total phase of a solar eclipse is 7 minutes and 32 seconds.

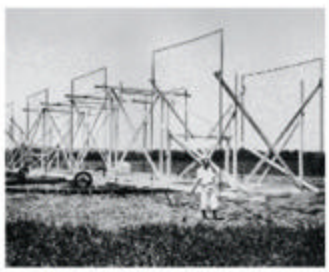
419 The oldest surviving planetary text is the Babylonian Venus tablet of Ammisaduqa, a seventh-century B.C. copy of a list of observations of Venus.

420 If you can spot the Andromeda Galaxy (M31) with your naked eyes, you can see something 14.7 billion billion miles away.

421 Neptune's moon Nereid has the most eccentric satellite orbit in the solar system — seven times as far at its farthest point from the planet as at its nearest point.

422 The largest single-dish optical telescope on Earth is the Gran Telescopio Canarias with a 36-part segmented mirror 409 inches in diameter.

423 Albert Einstein won the Nobel Prize in physics for his discovery of the photoelectric effect, not for his work on the theory of relativity.



424

WHAT STATION IS THAT?

In 1931, American Karl Guthe Jansky used a 100-foot-long, 20-foot-tall rotating antenna he built to discover radio waves coming from the Milky Way.

▲ Anaximenes provided the first complete view of the cosmos.

◄ Early cosmologies had Earth at the center.

425 THE COSMOS 1.0

Anaximenes was a Greek philosopher who lived in the city of Miletus c. 585–528 B.C. He believed everything in the world was made of air, and he applied this theory to explain the universe. Earth's flat disk, he said, was similar to a leaf floating on air. At some early point, Earth emitted bits of air that ignited to form the stars. He described the Moon and the Sun as being like Earth, but the Sun was on fire because of how fast it traveled. And while his ideas sound primitive today, Anaximenes provided the first view of the cosmos as a whole.

JEFFREY SCOVIL (INHALE); *ASTRONOMY*: ROEN KELLY (GOING); NRAO (STATION); DR. MANUEL/WIKIMEDIA (ANAXIMENES); UNIVERSITY OF NORTH FLORIDA (COSMOS)

The apparent size of the Andromeda Galaxy (left) will nearly rival the Milky Way roughly 3.8 billion years from now as the two start to collide.

426

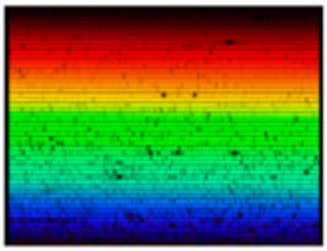
WHEN TWO BECOME ONE

Less than a century ago, astronomers thought the so-called Andromeda Nebula (M31) was a relatively nearby whirlpool of gas and dust surrounding a fledgling star. Its identity as the Milky Way's galactic neighbor would have to wait until American astronomer Edwin Hubble discovered in 1923 that the "nebula" lies far beyond any of our galaxy's stars and must be a separate entity.

Scientists now realize that M31 is bigger than the Milky Way and is on a direct collision course with our galaxy. Observations show that the two behemoths will make an initial close pass in a bit less than 4 billion years. (Sadly, life on our planet will have been extinguished long before; to watch the fireworks, our descendants will have to move elsewhere.) The impact will start slowly, but soon gas within the galactic disks will get compressed and unleash an unprecedented wave of star formation. Some 200 million years later, tidal forces will have distorted both galaxies beyond recognition. Ultimately, some 7 billion years from now, the two will have merged into a single giant elliptical galaxy astronomers have dubbed Milkomeda.

NASA/ESA/Z. LEVAY AND R. VAN DER MAREL (STSCI)/T. HALLAS/A. MELLINGER

Some 200 million years later, tides will have stretched the galaxies' spiral arms into elongated shapes that little resemble what we see now.



427

IT'S ELEMENTARY

In the 1860s, English astronomer William Huggins studied the stars Aldebaran and Betelgeuse with his spectroscope and found that they contain calcium, iron, magnesium, sodium, and more — the first proof that stars are made of similar materials as the Sun.

Joseph von Fraunhofer demonstrates his crowning achievement: the spectroscope he invented.

444 A POWERFUL TOOL

English physicist Isaac Newton first broke sunlight into its component colors in 1666. It wasn't until 1814, however, that German physicist Joseph von Fraunhofer invented a device that would spread out the solar spectrum so scientists could study the dark lines in it.

Most important to astronomy, Fraunhofer used his spectroscope with telescopes. He studied light from stars and planets, breaking it into spectra. In doing this, he laid the foundation for astrophysics. But Fraunhofer never understood what produced the lines he saw.

Work by English scientist Charles Wheatstone in the 1830s and German chemists Gustav Kirchhoff and Robert Bunsen starting in 1859 began the process of spectrum analysis. These researchers found the chemical elements responsible for some of the dark lines. This allowed later astronomers to determine what stars were made of.

But spectroscopy has yielded far more information, like how fast celestial objects are moving and whether toward or away from us, the strengths of stars' magnetic fields, and the temperatures of objects. Studying these lines also allows scientists to study wavelengths that the human eye cannot detect.

428 In 2014, Hubble Space Telescope scientists detected a galaxy that formed within 500 million years of the Big Bang.

429 So far, scientists have discovered exoplanets orbiting 35 of the approximately 1,400 stars within 50 light-years of Earth.

430 The Magnificent Seven is a group of nearby (within 1,000 light-years) middle-aged (several hundred thousand years old) isolated neutron stars cooling by emitting X-rays.

431 The most famous — and generally the best — meteor shower each year is the Perseids, which peaks around August 12 with rates around 60 "shooting stars" per hour.

432 Next to the Sun, the strongest consistent X-ray source (and also the first extrasolar X-ray source discovered) is Scorpius X-1, which lies 9,000 light-years away.

433 It would take nearly 70 constellations the size of Orion the Hunter to cover the entire sky.

434 The Voyager 1 spacecraft, currently traveling at 38,200 mph, will require another 14,000 years to travel 1 light-year.

435 The nearest star to the South Celestial Pole visible to the naked eye is magnitude 5.4 Sigma Octantis.

436 If an astronaut on the Moon watched Earth during a total lunar eclipse, our atmosphere's lower 5 miles would create a 4.3-arcsecond-thick ring of red around the planet.

437 Having lost part of his nose when he was 20 years old in a duel over a mathematical formula, Danish astronomer Tycho Brahe (1546–1601) wore prosthetic noses made of wood, copper, and brass.

438 The Sun is 400 times larger than the Moon, but also 400 times as far away, making both objects appear to be the same size in our sky.

439 Spacecraft observations show that over the past 20 years or so, Venus' rotation rate has slowed by 6.5 minutes.

440 The length of a galactic year, the time it takes our solar system to travel once around the Milky Way's core, is between 225 and 250 million years.

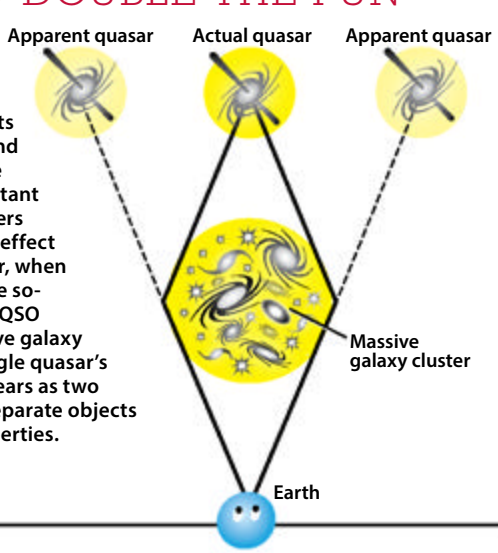
441 Our solar system orbits the Milky Way's center at a speed of roughly 500,000 mph.

442 The winds from massive stars are at least a hundred million times stronger than the solar wind emitted by our Sun.

443 Apollo 17's Eugene Cernan and Harrison Schmitt had the longest stay on the Moon: 74 hours, 59 minutes, and 40 seconds.

445 DOUBLE THE FUN

Albert Einstein's general theory of relativity predicts that massive objects warp space-time and can create multiple images of more distant objects. Astronomers didn't confirm this effect until 1979, however, when they discovered the so-called twin quasar QSO 0957+561. A massive galaxy cluster bends a single quasar's light so that it appears as two neighboring but separate objects with identical properties.



N. A. SHARP/NOAO/NSO/KITT PEAK FTS/AURA/NSF (ELEMENTARY); *ESSAYS IN ASTRONOMY*, D. APPLETON & CO., 1900 (POWERFUL); *ASTRONOMY*: ROEN KELLY (FUN)

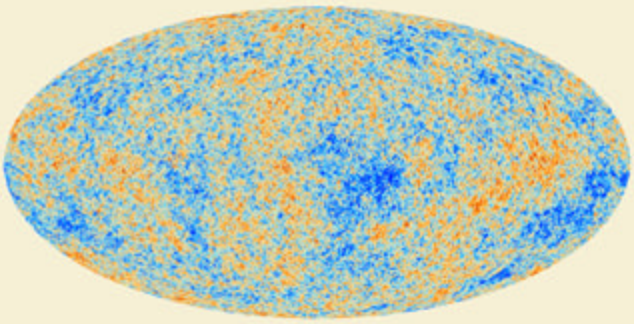
446

ONE GIANT LEAP

In the 200,000-year history of Homo sapiens, our species has accomplished some pretty amazing things. We invented the wheel, the printing press, and Velcro, and determined how stars shine and the cosmos began. But arguably the coolest thing we've done happened July 20, 1969, when American astronaut Neil Armstrong set foot on the Moon and humans could, for the first time, claim a second world as home. Even though more than half of the human population alive today did not experience the moment firsthand, "That's one small step for man, one giant leap for mankind" still resonates across nearly half a century of the space-time continuum.

After Armstrong stepped off the lunar module *Eagle*, he and his Apollo 11 crewmate Buzz Aldrin set about the more mundane tasks of deploying scientific instruments, collecting samples to return to Earth, and planting an American flag. Many of these artifacts will endure on the lunar surface as long as Homo sapiens can survive on its first home. In this image, photographer Armstrong captured Aldrin saluting the flag, with dozens of indelible footprints marking the formerly pristine surface.

NASA



447 OUT OF THE FOG

Just a few minutes after the Big Bang, the universe was a hot, dense soup of hydrogen nuclei (protons), helium nuclei, electrons, and electromagnetic radiation (light) in the form of photons. But the photons were essentially trapped in the burgeoning universe — they could travel only short distances before being absorbed and then re-emitted by some particle of matter.

That all changed approximately 380,000 years after the Big Bang. The universe had then cooled to a more modest 3,000 kelvins (nearly 6,000° F), at which point electrons and protons could capture one another and form into atomic hydrogen. The photons previously linked to unbound electrons and protons no longer had anything to interact with and were free to travel unimpeded. The universe became transparent to light and gave birth to the cosmic background radiation.

Of course, the expansion of the universe affects those photons just as it does the galaxies that formed a few hundred million years later. The light stretches to longer wavelengths, and those background photons now have wavelengths in the microwave part of the spectrum that reflect an overall temperature of 2.73 K. When astronomers discovered the cosmic microwave background in the 1960s, it provided the first observational proof that the universe began with a Big Bang. Modern measurements of this background light, such as this all-sky map from the European Space Agency's Planck satellite, reveal tiny temperature fluctuations (shown as color variations) that correspond to different densities — the seeds of the cosmic structure we see today.

448 Jupiter could contain the other seven planets in just 70 percent of its volume.

449 In 1675, Dutch astronomer Ole Rømer used eclipses of Jupiter's satellites to make the first determination of the speed of light.

450 Saturn's moon Hyperion has the lowest density of any solar system object, just 54 percent that of water.

451 The nearest brown dwarf is actually two of them in the binary system Luhman 16, which lies 6.59 light-years away in the southern constellation Vela.

452 Pluto will complete one orbit since its discovery (February 18, 1930) August 8, 2178.

453 Some 5,000 years ago, magnitude 3.7 Thuban (Alpha Draconis) was the North Star.

454 Stars don't twinkle until their light passes through Earth's atmosphere.

455 Neptune's moon Triton is the coldest known object in the solar system with an average surface temperature of –391° F.

456 Saturn's largest moon, Titan, is the only body in the solar system, apart from Earth, with a primarily nitrogen atmosphere.

457 French comet hunter Charles Messier discovered the first target on his famous list of deep-sky objects — the Crab Nebula (M1) — on August 28, 1758.

461 MIRROR, MIRROR

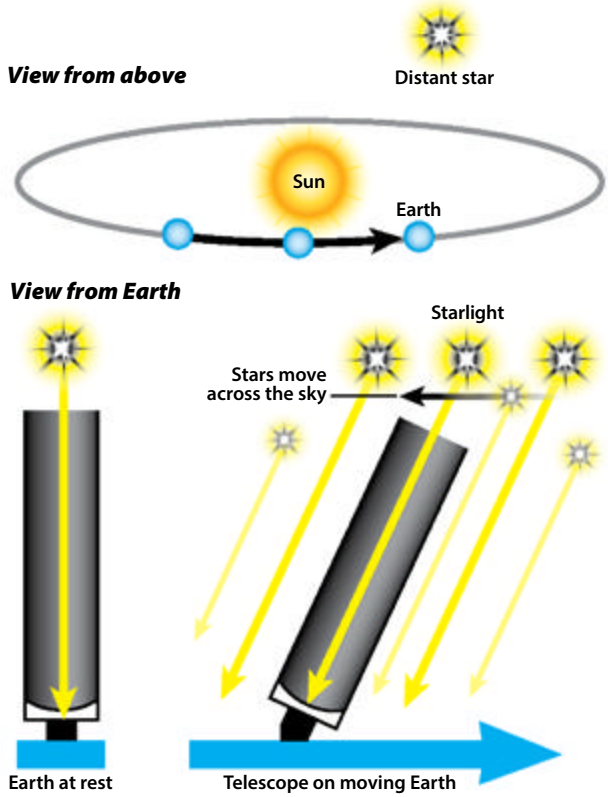
English physicist Isaac Newton built the first reflecting telescope in 1668.

458 The constellation with the highest overall brightness is Crux the Southern Cross; the one with the lowest overall brightness is Sextans the Sextant.

459 Jupiter's Great Red Spot, which rotates once approximately every six days, is an anti-cyclonic storm 22° south of the planet's equator.

460 The Greek astronomer Ptolemy used the reign of the Babylonian king Nabonassar, 747–734 B.C., to fix the beginning of an era because that's when he thought the earliest usable astronomical observations began.

462 RAINING STARLIGHT



By the 18th century, all astronomers believed that Earth revolved around the Sun and not vice versa, but they had no direct observational proof. English astronomer James Bradley provided confirmation in 1729 when he discovered the aberration of starlight. Essentially, he found that an observer has to point his or her telescope slightly in the direction of Earth's orbital motion for starlight to pass through the length of the scope's tube. The effect is similar to tipping your umbrella forward as you walk through rain, though much smaller, amounting to a tilt of at most about 20 arcseconds.

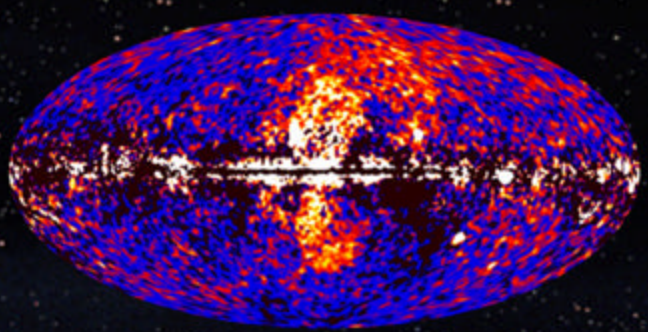
ESA/THE PLANCK COLLABORATION (FOG); ANDREW DUNN (MIRROR); *ASTRONOMY*: ROEN KELLY (STARLIGHT)

463

BLOWING BUBBLES

Astronomers have been mapping the Milky Way for centuries to learn its composition and shape. They've studied our galaxy in radio waves, X-rays, and everything in between. But it wasn't until November 2010 that they discovered two giant bubble-shaped structures above and below the Milky Way's center (illustrated above in purple). While analyzing data from NASA's Fermi Gamma-ray Space Telescope, scientists stumbled upon a pair of gamma-ray lobes with sharp edges that extend 25,000 light-years perpendicular to our galaxy's plane. Each has the energy of 100,000 supernovae and glows nearly uniformly in gamma rays.

After four years of studying these peculiar structures, astronomers still don't know their origin. One hypothesis involves a giant population of exploding massive stars; another is that our galaxy's central supermassive black hole is more active than previously thought. No idea perfectly fits the data so far, so the mystery of the Milky Way's bubbles remains.



The Fermi bubble signature from NASA's Fermi Gamma-ray Space Telescope (shown in blue) somewhat matches up with the microwave haze mapped by the European Space Agency's Planck satellite (shown in red and yellow), except the microwave lobe signatures don't extend as far as the gamma-ray ones.

NASA'S GODDARD SPACE FLIGHT CENTER (ILLUSTRATION); MICROWAVE: ESA/PLANCK COLLABORATION; GAMMA RAYS: NASA/DOE/FERMI LAT/DOBLER, ET AL./SU, ET AL. (DATA)

464 THE GLASS GIANT

On January 26, 1949, the 200-inch Hale Telescope at Palomar Observatory in California collected its first light from a celestial object — Hubble's Variable Nebula (NGC 2261). The instrument's construction had begun in 1934, but interruptions from World War II delayed its completion. The primary optic in the Hale Telescope was the first large mirror made of low-expansion Pyrex and the last to have a parabolic shape. (Current large telescopes have Ritchey-Chrétien optics, which employ a hyperbolic primary.) Grinding and polishing the mirror took 13 years and removed nearly five tons of glass. The Hale reflector reigned as the world's largest optical telescope until 1975.

465 The Chinese astronomer Gan De created the world's first star catalog in the fourth century B.C.

466 The brightest supernova in recorded history occurred in the constellation Lupus the Wolf in 1006.

467 Both the Eta Aquariid and Orionid meteor showers, which occur in May and October, respectively, are the result of particles shed by Halley's Comet.

468 The Persian astronomer Abd al-Rahman al-Sufi gave the first descriptions of the Andromeda Galaxy (M31) and the Large Magellanic Cloud.

469 A mysterious hexagon 60 miles tall has surrounded Saturn's north pole for at least 30 years.

470 Kepler's Nova, first seen in 1604, was the most recently observed supernova in the Milky Way.

471 The total energy collected by every radio telescope on Earth equals the energy of two snowflakes hitting the ground.

472 The pulsar PSR J1748–2446 is the fastest-spinning object known in the universe, rotating 716 times per second.

473 The process of falling into a black hole — getting more and more stretched out — is known as "spagettification."

474 The nearest star with a confirmed exoplanet is Gliese 674, which lies 14.8 light-years from Earth in the constellation Ara the Altar.

480

THAT'S NO COMET!

On March 13, 1781, German-born English astronomer William Herschel discovered Uranus from his garden in Bath, England.

475 The Milky Way's most distant globular cluster — PSO J174.0675–10.8774 — lies 473,000±55,000 light-years away.

476 Apart from the Moon, the satellite with the greatest number of named features is Io with 226.

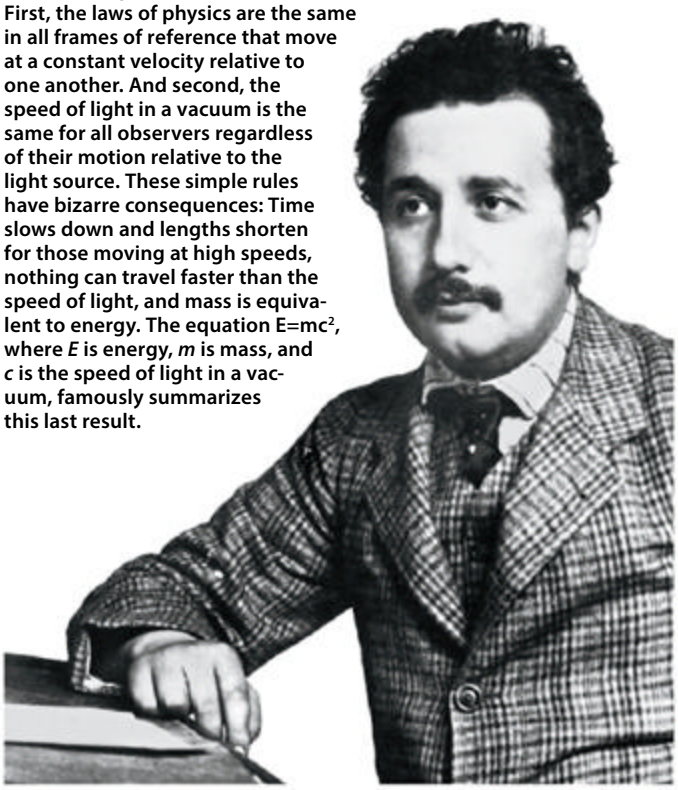
477 The 0 hour of right ascension (the position of the March equinox) was within the constellation Aries from 1865 B.C. to 68 B.C., and it is now in Pisces until 2597, when the age of Aquarius will dawn.

478 From the tiny moon Amalthea, Jupiter would span 45° of the sky.

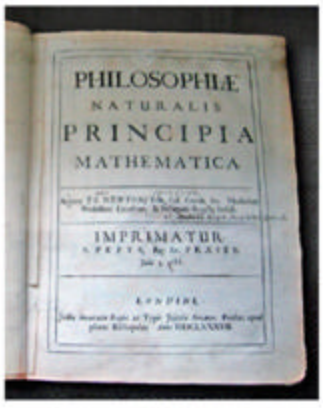
479 The Sun shines some 16 trillion times brighter than the faintest star visible to the naked eye.

481 PUNCH IT, CHEWIE?

When Albert Einstein published his special theory of relativity in 1905, he started with two postulates (assumptions he deemed to be true). First, the laws of physics are the same in all frames of reference that move at a constant velocity relative to one another. And second, the speed of light in a vacuum is the same for all observers regardless of their motion relative to the light source. These simple rules have bizarre consequences: Time slows down and lengths shorten for those moving at high speeds, nothing can travel faster than the speed of light, and mass is equivalent to energy. The equation $E=mc^2$, where *E* is energy, *m* is mass, and *c* is the speed of light in a vacuum, famously summarizes this last result.



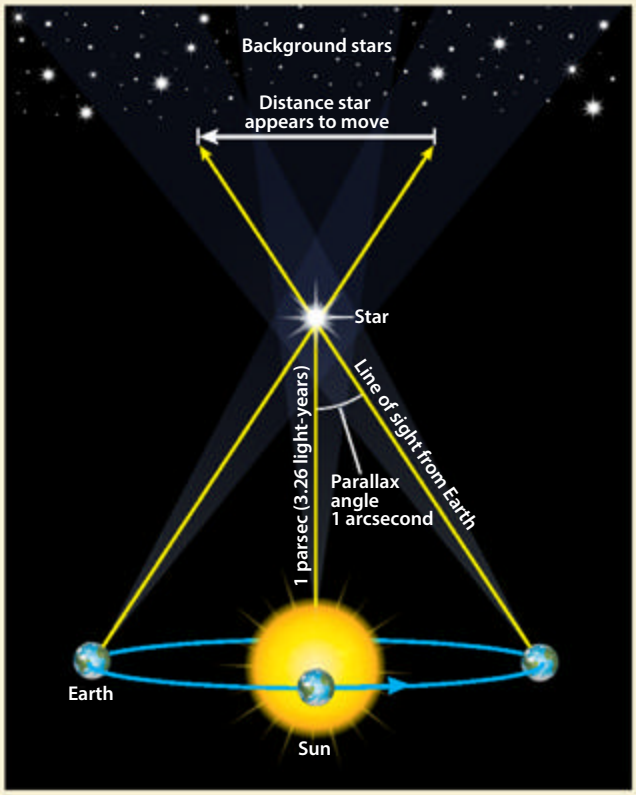
PALOMAR OBSERVATORY (GLASS); NATIONAL PORTRAIT GALLERY, LONDON (COMET); THE ALBERT EINSTEIN ARCHIVES (CHEWIE)



482

PHYSICS 101

Great minds prodded Isaac Newton to publish his *Philosophiæ Naturalis Principia Mathematica*, which became one of the most important texts ever written. The book describes Newton's laws of motion and universal gravitation in a marriage of mathematics and physics that invented classical mechanics and set the groundwork for every introductory college course. Its simple elegance helped send astronauts to the Moon and robotic emissaries throughout the solar system.



Stellar parallax allows astronomers to measure the distance to stars using geometry. A star 1 parsec (3.26 light-years) from Earth has a parallax angle of 1 arcsecond.

483 SHIFTY STAR

Parallax is the apparent shift of an object's position as seen from the extremes of Earth's orbit (six months apart). To demonstrate parallax, hold your hand straight out in front of you, giving the "thumbs up" sign. Now quickly blink between your left and right eye: Your thumb seems to jump back and forth against the background.

Two observations of a star, or other celestial object, six months apart provide different sightlines, just as when you blink your eyes back and forth. The star, like your thumb, will appear to move with respect to more distant stars when viewed from opposite points along Earth's orbit.

The parallax angle is half the angle between the two sightlines to the star. A star with a parallax angle of 1 arcsecond ($\frac{1}{3{,}600}$°) would be 1 parsec ("parallax second") from Earth.

In 1838, German astronomer Friedrich Bessel at Königsberg Observatory used the star 61 Cygni to make the first successful parallax measurement. He then determined the star's distance from Earth as 10.3 light-years. This estimate differed from the star's actual distance, 11.4 light-years, by about 10 percent.

484 Astronomers sometimes use a unit called a foe (10 to the power of Fifty-One Ergs, or 10^{51} ergs) to measure the energy released by a supernova.

485 The solar cycle of sunspots currently averages about 11 years from peak to peak and has been proceeding uninterrupted since the early 18th century.

486 According to an August 2011 paper, 8.3 percent of Earth-like planets are likely to have a Moon-like satellite.

487 The four Royal Stars of the ancient Persians were Aldebaran (Alpha Tauri), Antares (Alpha Scorpii), Fomalhaut (Alpha Piscis Austrini), and Regulus (Alpha Leonis).

488 In the 1910s, American astronomer Harlow Shapley found that 93 globular clusters he was studying formed a spherical distribution centered on a spot in Sagittarius between 25,000 and 30,000 light-years from Earth — the center of the Milky Way Galaxy.

489 In 46 B.C., Julius Caesar adopted a 365¼-day year, first proposed by the fourth-century B.C. Greek astronomer Callippus.

490 As of December 15, 2014, astronomers have confirmed 1,854 extrasolar planets orbiting 1,163 stars.

491 The Moon's atmosphere is less than a hundred-trillionth the density of Earth's atmosphere at sea level.

492 Saturn is the flattest planet; its polar diameter is only 89 percent of its equatorial diameter.

493 Scientists estimate that the earliest stars formed some 200 million years after the Big Bang.

494 The Sun destroyed Comet ISON (C/2012 S1) as it reached perihelion November 28, 2013.

495 On April 23, 2014, NASA's Swift satellite detected an explosion on the star DG Canum Venaticorum 10,000 times more powerful than the largest solar flare ever recorded, the strongest stellar flare ever seen from a nearby red dwarf.

496 In 2005, astronomers using the Spitzer Space Telescope announced that the Milky Way is a barred spiral galaxy.

497 Only 24 astronauts have traveled beyond low Earth orbit; all were part of the Apollo Program.

498 By volume, exactly 1,321 Earths could fit inside Jupiter.

499 NASA data show that between 1994 and 2013, small asteroids impacting Earth's atmosphere resulted in 556 individual bolide (fireball) occurrences.

WELLCOME LIBRARY, LONDON (NEWTON); ANDREW DUNN, CREATIVE COMMONS (*PRINCIPIA*); *ASTRONOMY*: ROEN KELLY (STAR)

"From this distant vantage point, the Earth might not seem of any particular interest.

But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there — on a mote of dust suspended in a sunbeam."

— Carl Sagan

500

PALE BLUE DOT

Earth appears as but "a mote of dust" in this iconic image made famous by Carl Sagan. The science popularizer had long pushed NASA to turn Voyager's gaze home to take this snapshot, but was met with reluctance. Mission managers feared camera damage from the Sun's rays. The image became an instant sensation when NASA finally captured it in 1990 from a distance of 4 billion miles. A chance reflection of sunlight off the spacecraft breaks up a field of black, and Earth occupies just a few pixels. Of course, even more powerful than the pixelated image are Sagan's chilling words that commonly accompany it. The two are now permanently linked in the public psyche.

NASA/JPL

OBSERVING**BASICS**

BY GLENN CHAPLE

Astronomical game plans

Observe with a purpose thanks to the Astronomical League.

If you participate in any form of competitive sport, you likely belong to an organized league. Unless you consider the Messier marathon or the quest to be the first to discover the next comet, backyard astronomy doesn't qualify as a competitive sport. Nevertheless, we have a league of our own. It's called the Astronomical League, and I urge you to become a member. An email from Roger Ivester, of Boiling Springs, North Carolina, explains why.

Ivester notes, "I've always believed that when a new or old observer has a list [of objects to observe], they are much more likely to stay involved with amateur astronomy. I call this observing with a purpose. Without it, many lose interest."

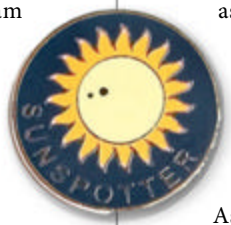
Ivester is right. If all you do is go outside now and then for a quick peek at the Moon, one of the planets, or a showpiece deep-sky object or two, you won't be an active backyard astronomer for very long. With a reachable goal or purpose, such as observing all of the objects in the Messier catalog, you have an incentive to become wholeheartedly engaged in the hobby. Through its various observing programs, the Astronomical League provides those incentives.

The Astronomical League offers to its members nearly 50 goal-oriented observing clubs that accommodate a diversity of observing skills and equipment, from novice using only the unaided eye to veteran working with a huge Dobsonian telescope. Individuals who complete each program send a copy of their observations to the program coordinator for verification and, upon acceptance, receive a certificate and award pin. Who says only sports-oriented leagues give out awards?

To illustrate a typical Astronomical League observing program, let me describe my own experience with the one devoted to double stars. The goal is to put together a logbook that includes sketches and descriptive notes for the 100 showpiece pairs on the program list. Over the years, I've viewed more than 1,500 double stars, including almost all of these 100. Instead of assuming a "been there, done that" attitude, I embraced the challenge. In the process, I reacquainted myself with double stars I hadn't seen in years. Viewed with a more patient, trained eye, they looked more beautiful than ever. The moral of this account? Even an Astronomical League observing program designed for the novice or intermediate observer can benefit the seasoned telescopist.

What next? The Carbon Star Observing Program looks pretty interesting. In recent years, these ruddy-hued gems have seen an upswing in popularity. Programs devoted to deep-sky binocular targets, lunar observing, meteors, and globular clusters might be worth looking into. The Astronomical League even has a Sketching Observing Award. Fans of Erika Rix's column (myself included) should have fun with that one! Maybe I'll really challenge my observing skills by tackling the Herschel 400 Observing Program — that should keep me busy for a year or two … or three. Decisions, decisions!

If astronomical ennui has you sidelined, look over the list of Astronomical League observing programs on its website (www.astroleague.org) to find one (or more) that interests you. If you're not already an Astronomical League member, consider joining. Its website lists the many member benefits (besides the observing programs) that the Astronomical League offers. Individuals not associated with an astronomy club or who belong to one not affiliated with the Astronomical League can join as a Member-at-Large. As Ivester and I would say, get a list and bring new purpose to your backyard observing.



And on a quick side note, in my August 2013 column, I described the "Butterfly Alphabet," a remarkable poster showing all the letters of the alphabet, plus numerals 0 through 9, as found in patterns on the wings of butterflies and moths. I asked readers to send me astroimages that might be applied to a "Cosmic Alphabet" (my thanks to those of you who did). To complete the project, I still need the letters (capitals, please) B, D, F, and R, and the numbers 2 and 4. See what you can come up with, either on images you've taken or from those gleaned off the Internet (public domain, please) and forward them to my email address below.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: A tour of Astronomy.com. Clear skies!

FROM OUR INBOX

Opportunity missed

While I have been thrilled with the magazine's effort to include many female scientists and experts throughout the years, I was disappointed when I read the article "Where is astronomy going?" by Sarah Scoles in the September issue (p. 24). Not one scientist of color — Hispanic, African-American, Asian — was quoted or pictured. Surely there are some. What a great opportunity missed to showcase smart people of all colors and sexes looking ahead to the future, providing a glimpse to all people what is ahead for science. **— Kathy Kudravi,** Peachtree Corners, Georgia

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

WEBTALK

What's new at Astronomy.com.
BY KARRI FERRON

REGISTER TODAY! Go to www.Astronomy.com/register for access to bonus articles, photos, videos, and more.

COOLEST SPACE FACTS CONTEST

Enter for a chance to win a CELESTRON TELESCOPE!

This special 500th issue of *Astronomy* was a lot of fun for the staff to put together. After all, covering the coolest things about our favorite subject is really why we work for the magazine in the first place. Each of us has our favorites among the various facts you'll find throughout the special "500 coolest things" section, and now we want to know yours. Do historical discoveries make the top of your list? Or are you a fan of the weirdest objects in the universe? Is your pick focused on a certain subject, like planetary science? Or are the coolest things about space for you truly varied? We want to find out your favorites with the Coolest Space Facts Contest, which runs January 26 to February 28.

Members of the *Astronomy* staff will read all the entries and pick their favorite by March 16. The winner will receive a Celestron 114AZ telescope, a 4.5-inch Newtonian reflector. With its included eyepieces, this instrument provides superb views of the Moon, bright planets, and comets. It's a great beginner telescope and has received rave reviews throughout the amateur astronomy community, including from *Astronomy* Contributing Editor Mike Reynolds. For complete Coolest Space Facts Contest rules and to enter to win the Celestron 114AZ, visit **www.Astronomy.com/500contest**.

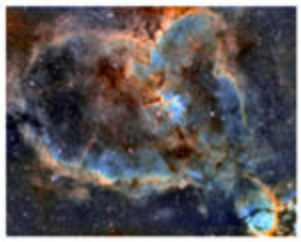
OBSERVING TOOLS

The Sky this Week

This daily digest of celestial events highlights the brightest objects you can observe each night. In 10-day increments, learn when and where to spot each planet, the best meteor showers, bright comets and asteroids, notable constellations, asterisms, and variable stars, a few deep-sky objects, and more. Each daily entry offers essential details of the event or object and how to locate it in your sky. See what's happening tonight at **www.Astronomy.com/skythisweek**.

COMMUNITY

Reader Photo Gallery



Browse thousands of beautiful astro-images like this one of the Heart Nebula (IC 1805) by Ajay Narayanan, and submit your own. Not an astroimager? You still can explore our numerous gallery catalogs. Comment on photos and learn from other imagers' techniques. Beginners and advanced amateurs anywhere in the world are welcome at **www.Astronomy.com/readergallery**. We publish new photos regularly!

FOLLOW *ASTRONOMY*
www.twitter.com/AstronomyMag
www.facebook.com/AstronomyMagazine
plus.google.com/+astronomymagazine

TAKE THE UNIVERSE with you

ASTRONOMY'S DIGITAL EDITION lets you:

* Link to website content, blogs, advertisers' websites, audio, and video.
* Zoom in and magnify to see all the details of *Astronomy*'s stunning images.
* Take your issues with you wherever you go — and save on storage space!

ASTRONOMY.COM/DIGITALSUB

Powered by Zinio™, digital editions are available on PC; Macintosh; Android™; iPad®; iPhone®; and Windows 8.
Zinio is a registered trademark of Zinio, LLC. Android is a registered trademark of Google Inc. iPad and iPhone are trademarks of Apple Inc., registered in the United States and other countries. Windows is a registered trademark of Microsoft Corporation in the United States and other countries. P24529

BY ERIKA RIX

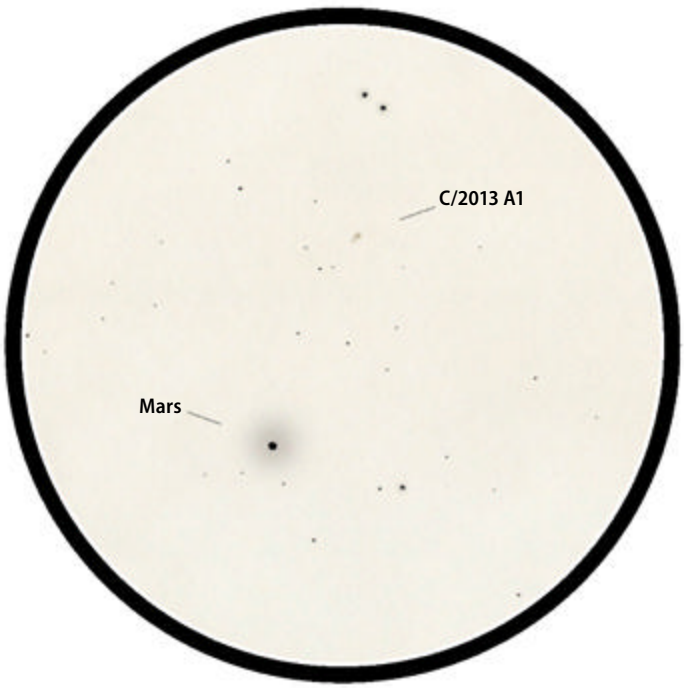
An award for sketching

In case you missed it, the Astronomical League recently added an observing program dedicated to sketching. The Haleakala Amateur Astronomers of Maui, Hawaii, created a target list to help observers heighten their appreciation for astronomical sketching and to sharpen their recording skills. The program went live in September 2014 and consists of 114 choices ranging from deep-sky and solar system objects to astronomical events.

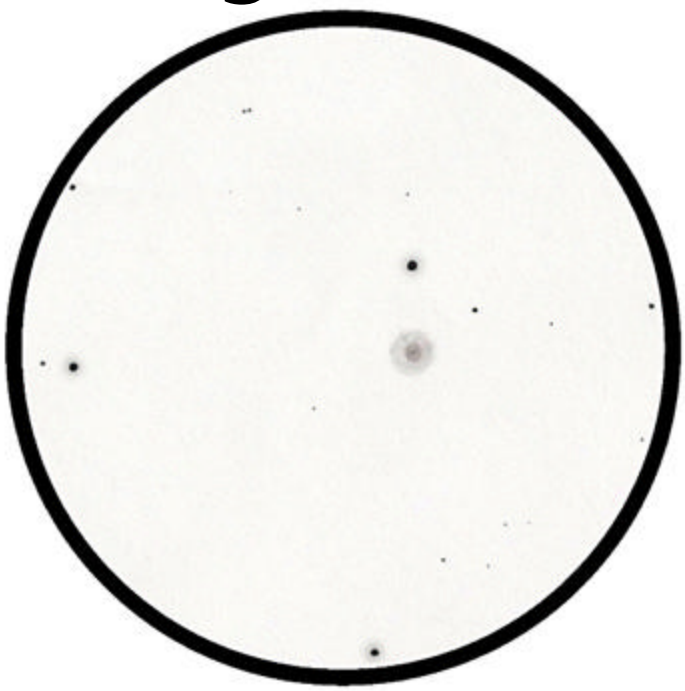
To participate, you must be an Astronomical League member (either through an astronomy club or at large) and sketch at least 75 of the listed objects. You can use up to 10 previous sketches, so you might want to save those for special ones that you've already logged. For instance, I'll toss in a 2013 sketch of the Double Cluster — I don't relish another two-night session of star plotting! For this column, I decided to share two of the images I submitted.

For the comet entry, I took advantage of Comet Siding Spring's (C/2013 A1) close encounter with Mars on October 19, 2014. Siding Spring is an Oort Cloud comet discovered by Robert McNaught in January 2013. On the night of its Mars flyby, it had an apparent magnitude of 11, and at 16h28m UT, it passed roughly 85,000 miles (137,000 kilometers) from the Red Planet against the starry background of the constellation Ophiuchus.

The time of my sketch was just 8½ hours later. Both objects easily fit in the field of view of an eyepiece that gave a magnification of 138x in a 16-inch scope. Because of its close proximity to Mars (16' separation), the comet was too dim to catch without first placing Mars just outside the field. Once I located it, I nudged the scope so that I could see the two together. Overall, Siding Spring was faint with a slightly brightened, condensed coma. I also could see a short, diffuse tail stretching north to south.



The author sketched Comet Siding Spring (C/2013 A1) and Mars on October 20, 2014, at 1h UT. For both sketches shown on this page, she used a 16-inch f/4.5 reflector on a Dobsonian mount. Here, she observed through a 13mm eyepiece, which yielded 138x. Her sketch media included 70 lb. white Canson drawing paper, a super-fine black felt artist pen, a 0.5mm mechanical pencil, and a blending stump. BOTH SKETCHES: ERIKA RIX



For the Eskimo Nebula (NGC 2392), the author used an 8mm eyepiece (225x), attaching an Oxygen-III filter to capture extra detail in the nebula. She used white printer paper, a super-fine black felt artist pen, a 0.5mm mechanical pencil, and a blending stump. She rotated both sketches in Photoshop so that north is at the top with west to the right.

The second entry I want to discuss here is one of the 12 planetary nebulae listed in the observing program — the Eskimo Nebula (NGC 2392) in Gemini. William Herschel discovered this object in 1787. It began its formation roughly 10,000 years ago when high-velocity winds from its dying star pushed material into two elliptical lobes. Through earthbound telescopes, one lobe obscures part of the other, so the planetary resembles a person's face wrapped within a fur parka.

Located just 1.6' south of an 8th-magnitude star, the Eskimo Nebula measures 47" by 43" with a magnitude of 9.2. This bluish example of star death is a treat regardless of telescope size. You can spot the magnitude 10.5 central star even through a 4-inch scope.

Increase to an 8-inch instrument, and you'll see the nebula divided in half by a distinct dark ring. Through a 16-inch scope, the central disk becomes brighter, revealing its two shells for that face-in-a-parka guise.

You'll find more information on the Astronomical League's program at www.astroleague.org. Here's wishing you success on achieving the Sketching Observing Award. Comments or suggestions? Contact me at erikarix1@gmail.com.

NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

10mm eyepiece

Celestron, Torrance, California

Celestron's Ultima Duo 10mm Eyepiece offers a 68°-wide apparent field of view and 20 millimeters of eye relief. It contains eight optical elements in five groups, all of which are fully multicoated. The barrel has integrated 42mm T-adapter threads as well as internal threading to accept filters.

Price: $129.95
[t] 310.328.9560
[w] www.celestron.com

Smartphone adapter

iOptron, Woburn, Massachusetts

iOptron's Universal Smartphone Eyepiece Adaptor makes it easy to use your smartphone to view and save photos (or video) of anything you can see through your telescope. Simply adjust the bracket to fit any make or model smartphone device, and then fit the included 12.5mm eyepiece into your telescope.

Price: $58
[t] 866.399.4587
[w] www.ioptron.com

2.4-inch refractor

Stellarvue, Auburn, California

Stellarvue's SV60EDS is a 2.4-inch apochromatic refractor with a two-element f/5.5 objective made from Ohara FPL-53 glass. The scope comes with an aluminum clamshell mount that has a Vixen-style rail and a finder scope shoe. The optical tube weighs just 2.5 pounds (1.1 kilograms).

Price: $599
[t] 530.823.7796
[w] www.stellarvue.com

Mount

Sky-Watcher USA
Torrance, California

Sky-Watcher USA's Star Adventurer Photo Package mount provides various setting combinations for astrophotography and time-lapse photography. It has sidereal, solar, and lunar tracking and includes automatic DSLR shutter-release control. The mount can carry an 11-pound (5 kilograms) payload.

Price: $319
[t] 310.803.5953
[w] www.skywatcherusa.com

SEE REPORTS ON 350+ PRODUCTS AT **www.Astronomy.com/equipment.**

JOIN *ASTRONOMY* MAGAZINE'S

AURORA ADVENTURE

OCTOBER 5–15, 2015

Experience a once-in-a-lifetime northern lights tour along the Norwegian coast and interior with *Astronomy* magazine and TravelQuest International. The trip includes:

- 6 nights of dark-sky aurora viewing
- 4 days cruising Norway's fjords aboard the MS *Nordnorge*
- 3 days exploring past and present Sami culture
- Lectures and night sky viewing with *Astronomy* staff
- Guided tours by local experts
- And much more!

Astronomy magazine TRAVELQUEST international

RESERVE YOUR SPOT TODAY!

Visit www.astronomy.com/norway

P23642

ASTRONOMY.COM

brings the sky above to you with these great subscriber-only benefits:

You'll receive:

- **Equipment review archive** – Expert analysis of 200 + telescopes, binoculars, cameras, and more!
- **StarDome Plus** – Your personal guide for locating stars, planets, asteroids, and more!
- **Star Atlas** – 24 zoomable star charts show 45,000 stars and 800 deep-sky objects!
- **The sky this month** – Your road map to each month's observable celestial events!
- **Ask Astro** – The informative source that answers reader questions with expert explanations.
- **Multimedia gallery** – A vast collection of pictures, movies, and audio.
- **PLUS**, many more Web site extras available only to subscribers!

Visit **Astronomy.com** today!

Astronomy magazine

P21454 photo credit: ESO

ADM Accessories
716-830-0413
Anthony Davoli
sales@admaccessories.com
www.admaccessories.com

ECLIPSE SHADES™
Safe Solar Viewers
CE Certified
Rainbow Symphony, Inc.
818-708-8400 • Fax 818-708-8470
www.rainbowsymphony.com

Bob's Knobs
Meade, Celestron, Intes, Takahashi . . . and more!
6976 Kempton Rd.
Centerville IN 47330
765-855-5109 USA
www.bobsknobs.com

Deep-Sky Planner 6
Comprehensive planning & logging software
Astronomy 2013 Star Products
www.knightware.biz

Build Your Own
Custom Astronomical Adapter
www.preciseparts.com
+1 305 253-5707
info@preciseparts.com
PRECISEPARTS

Optical Coatings
Parabolic Mirrors
Testing
Refiguring
OPTIC WAVE LABORATORIES
www.OpticWaveLabs.com

The Original And The Best!
OBSESSED?
Take it with you.
New UC 18" f/4.2 Ultra-Compact fits in any car.
With the same superior quality and performance that Obsession™ 'scopes are known for.
Full line of big apertures from 12.5 to 25 inches.
See them all online.
Send for free flyer & video
PO Box 804a, Lake Mills, WI 53551 (920) 220-1195
OBSESSION TELESCOPES™
www.obsessiontelescopes.com

HOME-DOME AND PRO-DOME OBSERVATORIES
PROFESSIONAL DESIGN - AMATEUR PRICE
★ 6, 10, & 15 ft. Diameter
★ Stand-alone or On Building
★ All Fiberglass
★ Easy Assembly
★ Manual/Computer Automated
★ Full Height/Handicap Access
★ Priced from $3,295
CloudWatcher
Low cost, accurate system to detect cloud cover, light levels and first traces of rain. With DDW interface.
www.clouddetection.com
Call or write for FREE Brochure
TECHNICAL INNOVATIONS
Phone: 407-601-1975 • www.homedome.com

Keeping it "Beautifully" Simple
Almost Zero Add-Ons... Robotic right out of the box
Almost Zero Installation... Takes hours not months
Astro Haven Enterprises
domesales@astrohaven.com
949.215.3777 www.astrohaven.com

The Greatest Southern Sky Experience
NOVEMBER 5-11, 2015
Experience an exclusive and unforgettable week discovering the "Secrets of Chile" with Bob Berman
See the Andes, the Atacama Desert, astonishing skies from a private mountain-top observatory and incredible wildlife among other wonders.
For More information on the Chilean Southern Sky or March, 2015 Northern Lights tours, write us us at:
BobBermanAstronomyTours@gmail.com
call 845-901-7049 or visit
BermanAstronomyTours.com

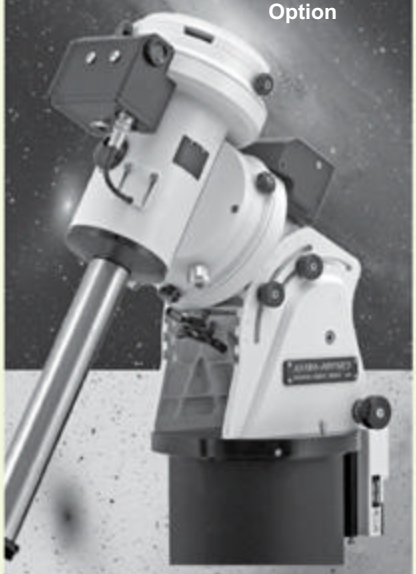
ASTRO-PHYSICS

Dedicated to Craftsmanship!

New!!! 1100GTO

Portability & Capacity

Absolute Encoder Option



www.astro-physics.com
Machesney Park, IL USA
Ph: 815-282-1513

Far West Texas Ranch For Sale
Home +/- 7240 Acres River Front Canyon Land
Newly renovated & fully furnished. Dark Skies, various observation points. $2,715,000.
For more information:
www.landsofamerica.com/member/53998
or call Lenk Real Estate 713-385-3801

ScopeStuff
Telescope Accessories & Hardware
World's largest inventory of telescope accessories, adapters and hardware. Free shipping in the USA!
www.scopestuff.com
512-259-9778

all sky cam
Day and night
View from anywhere
360° horizon to horizon
660-675-5066
www.MoonglowTech.com

See the Universe in color live with
MALLINCAM
Astronomical Video CCD Cameras
MALLINCAM.COM

Howie Glatter's Laser Collimators & Accessories
tuBlug ™ and Blug™ Barlowed collimation aids
- SkyPointers™ & brackets
- Glatter Mirror Sling kits
SEE US AT NEAF
The Parallizer™
2"-1.25" adapter for Perfect Parallel Alignment
Howie Glatter 3850 Sedgwick Ave. Bronx, N.Y. 10463
Tel/Fax (718) 796 3203
www.skypointer.net www.collimator.com
e-mail: howieglatter@mindspring.com

REWARD
$1,000.00
will be paid to the first person to disprove "The AP Theory"
(see page 17 of this edition)
1. One theory cannot be used to disprove another theory
2. All facts must be verified by an encyclopedia
3. Must include successful experiments and specific details
4. One example in nature must be submitted
Theory: www.aptheory.info
Comments: aptheory@aptheory.info
no purchase necessary

STELLARVUE
HAND CRAFTED REFRACTORS
SEEING IS BELIEVING
NEW SVA130EDT APOCHROMAT
Intro Price: $3195

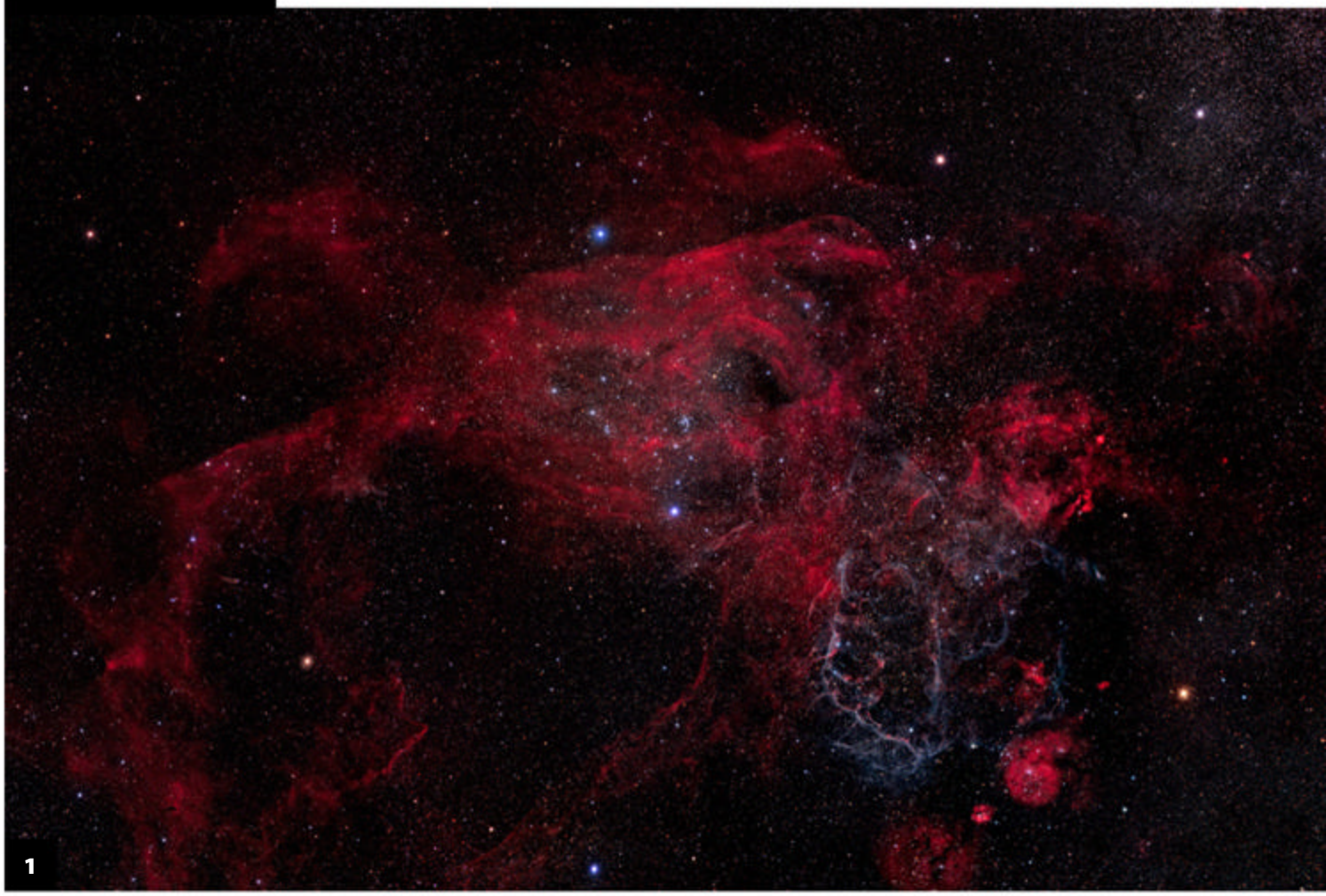
WWW.STELLARVUE.COM
11820 KEMPER ROAD
AUBURN, CA 95603
(530) 823-7796

INDEX *of* ADVERTISERS

ADM Accessories 86
Adorama 19
AP Theory 17, 87
Ash Manufacturing 21
Astro Haven 86
Astro-Physics 87
Astrodon 15
Astronomy magazine - Digital Edition 83
Astronomy Travel Tours 8, 85
Bob Berman Tours 86
Bob's Knobs 86
Celestron 2, 92
Glatter, Howard 87
iOptron 17
Jewelry Designs for Men 19
Knightware 86
MallinCam 87
Moonglow Technologies 87
Mr. Starguy - Vixen Optics 8
Oberwerk Corporation 19
Obsession Telescopes 86
Oceanside Photo & Telescope 5
Optic Wave Laboratories 86
Precise Parts 86
Rainbow Symphony 86
Sandra Haddock 87
ScopeStuff 87
Simulation Curriculum Corporation 17
SkyWatcher - USA 91
Software Bisque, Inc. 15
Stellarvue 87
Technical Innovations 86
Tele Vue Optics, Inc. 3
The Teaching Company 7
Vernonscope, LLC 15
Woodland Hills Cameras & Telescope 21

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

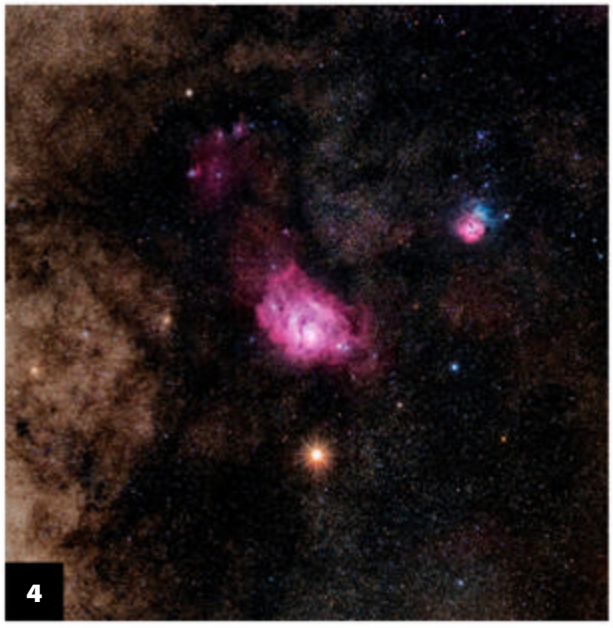
READER GALLERY



1. STAR DEATH
The Vela Supernova Remnant (SNR) formed when its progenitor star exploded some 11,000 years ago. Its shock wave still interacts with the thin material between stars, producing light of several hues. At a distance of 800 light-years, the Vela SNR is one of the closest such objects to Earth. (FLI ProLine PL-16803 CCD camera, Canon 200mm lens set at f/4, six-panel mosaic, each frame is an HαLRGB image with exposures of 30, 20, 30, 30, and 30 minutes, respectively)
• ***Gerald Rhemann***

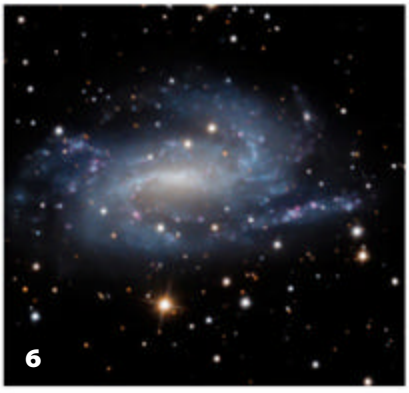
2. EVIL-LOOKING CLOUD
LDN 1251 is a faint region of dark nebulosity in Cepheus. Cold gas and dust are the main components of this star-forming region. The galaxy PGC 166755 lies above the cloud at upper center. (5.2-inch APM Telescopes LZOS 130/780 refractor at f/4.5, FLI MicroLine ML-8300 CCD camera, 6.5 hours of luminance exposures stacked with 5.5 hours of RGB data) • ***Jeffrey Weiss***

3. STARRY SEA
The Sailboat Cluster (NGC 225) is an open star cluster in the constellation Cassiopeia. This image, which combines some 19 hours of exposures, shows lots of reflection nebulosity as well. (17-inch PlaneWave corrected Dall-Kirkham reflector, SBIG STXL 11002 CCD camera, LRGB image with exposures of 450, 216, 198, and 300 minutes, respectively) • ***Bill Snyder***



4. MARS AND TWO NEBULAE
Mars (below center), gleaming at magnitude 0.9, passed the Lagoon Nebula (M8, center) and the Trifid Nebula (M20, to the upper right of M8) this past October. At the time, the nebulae were some 150 million times as far away as the planet. (Canon 5D Mark II DSLR, Canon 200mm L lens at f/5.6, ISO 1600, ten 10-minute exposures, stacked, taken October 23, 2014, at 9 P.M. EDT from the Stardust Ranch near Okeechobee, Florida) • ***Derek Demeter***

5. OFF-KILTER GALAXY
NGC 55 is a large barred spiral galaxy located approximately 7.2 million light-years away in Sculptor. Most of its material seems concentrated on one side. (3.6-inch Astro-Tech AT90EDT refractor at f/6.7, SBIG ST-8300m CCD camera, LRGB image with exposures of 120, 40, 40, and 40 minutes, respectively) • ***Dan Crowson***



6. LOOSELY WOUND
NGC 925 is a barred spiral galaxy in the constellation Triangulum. It belongs to the NGC 1023 Group, which may have a total of 15 members. (14-inch Officina Stellare RC-360AST Ritchey-Chrétien reflector at f/8, Apogee Alta U16M CCD camera, LRGB image with exposures of 270, 80, 80, and 80 minutes, respectively) • ***Bob Fera***

7. COLORFUL SKY
While in Alaska, this photographer saw a week of terrific auroral displays. This one came with excellent sky quality as well, as evidenced by the pinpoint stars near the horizon and the sight of the Andromeda Galaxy (M31) to the lower right. (Canon EOS-1D X DSLR, Nikkor 14–24mm lens at f/2.8, ISO 1600, 25-second exposure, taken March 27, 2014, at 12:30 A.M. local time in the Brooks Range in Alaska) • ***Chris Madeley***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

MAX ALEXANDER

Stars over the William Herschel Telescope

The 4.2-meter William Herschel Telescope is one of the workhorse instruments at the Roque de los Muchachos Observatory on La Palma in the Canary Islands. Perched at an altitude of 7,690 feet (2,344m), the telescope is the second largest in Europe, only beat by its neighbor, the 10.4-meter Gran Telescopio Canarias. When it was constructed in 1987, the Herschel Telescope was the third-largest optical telescope in the world.

Famous for its studies in the optical and infrared, the Herschel Telescope is known for many notable discoveries, including the first detection of the supermassive black hole at the center of the Milky Way, the first optical detection of a gamma-ray burst, and the first spectrum of an asteroid that subsequently struck Earth.

English astroimager Max Alexander, based in London, also an active Starmus Festival fellow, captured the Milky Way looming over the Herschel Telescope several years ago.

THE NEW BIG THING

ISN'T VERY BIG AT ALL

THE SKY-WATCHER STAR ADVENTURER™ MOUNT
PORTABLE, POWERFUL AND PRECISE

The new Sky-Watcher USA Star Adventurer multi-purpose mount is perfect for anyone — Milky Way photographers, eclipse chasers and all of you astronomers on the go. It's the ideal night-and-day, grab-and-go package.

Compact and portable — weighing only 2.5 pounds — this versatile mount is also powerful. Its quality construction, utilizing precision all-metal gearing, provides an impressive 11-pound payload capacity.

The Star Adventurer converts easily from a tracking photo mount to a grab-and-go EQ astronomical mount. Allowing you to spend more time doing what you love and less time setting up.

The Star Adventurer features:

- Multiple preprogrammed speeds perfect for time-lapse photography, wide angle astrophotography and astronomical tracking
- Tracking selectable between multiple sidereal rates, Solar and Lunar
- Built-in polar scope with illuminator
- DSLR interface for automatic shutter control
- Built-in auto-guiding interface
- Long battery life — up to 11 hours
- External Mini USB power support
- Compatible with 1/4-20 and 3/8 inch camera tripod threads

Star Adventurer Astronomy package
Only $339

Star Adventurer Photo package
Only $319

So, if you're ready to grab one of these perfect grab-and-go packages, just visit our web site or one of our authorized dealers.

Optional accessories

Dec bracket - $40 *Ball head adapter - $15*
Latitude base - $65 *Counterweight kit - $30*

Product shown with optional accessories. OTA and camera not included.

©2014 Sky-Watcher USA. Specifications subject to change without notice. 20s 14028
Contrary to what you may have heard elsewhere, small is not necessarily a bad thing.

Sky-Watcher® USA
Be amazed.

For information on all of our products and services, or to find an authorized Sky-Watcher USA dealer near you, just visit **www.skywatcherusa.com**.
Don't forget to follow us on Facebook and Twitter!

CELESTRON

HD Pro Wedge and 80 mm Guidescope sold separately.

EXCEPTIONAL VIEWS. SUPERIOR PERFORMANCE. NO COMPROMISE.

CPC AND CPC DELUXE HD

Instantly recognizable by their dual fork arm mounts, the Celestron CPC and CPC Deluxe HD have become favorites at star parties worldwide. This year, bring home the iconic CPC or CPC Deluxe HD and experience the views for yourself.

WITH CPC, YOU GET THE BEST OF CELESTRON'S 55 YEARS OF INNOVATION:

+ Rock-solid dual fork arm mount with precision drive base and mechanics
+ Celestron's signature Schmidt-Cassegrain optics in sizes from 8-11 inches
+ SkyAlign technology so you are aligned and ready to observe in minutes, without having to know the name or location of any star
+ NexStar+ hand control with 40,000+ object database
+ Internal GPS
+ Ready for astrophotography with All-Star Polar Alignment and optional HD Pro Wedge
+ Compatible with Celestron's latest accessories: StarSense AutoAlign for quick, self-guided alignment or SkyQ Link 2 WiFi Module for wireless control with your smartphone or tablet

STEP UP TO THE CPC DELUXE HD FOR EVEN BETTER PERFORMANCE:

+ Celestron's proprietary EdgeHD optics for pinpoint stars all the way to edge of the field with the widest eyepieces and largest imaging sensors
+ Reengineered worm gear motor drive provides smoother tracking

CELESTRON PREMIER SELECT DEALERS

OPT Telescopes – 800.483.6287 – www.opttelescopes.com
B&H Photo – 800.947.9970 – www.bhphotovideo.com
Hands On Optics – 866.726.7371 – www.handsonoptics.com
Astronomics – 800.422.7876 – www.astronomics.com
Adorama – 800.223.2500 – www.adorama.com
High Point Scientific – 800.266.9590 – www.highpointscientific.com
Optics Planet – 800.504.5897 – www.opticsplanet.com
Focus Camera – 800.221.0828 – www.focuscamera.com
Woodland Hills – 888.427.8766 – www.telescopes.net

DISCOVER MORE AT
celestron.com

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

May 2015: Saturn's gorgeous rings

May's evening sky bristles with tempting planetary targets. The brightest of the group is **Venus**, which hangs low in the northwest as darkness falls and sets shortly before 8 P.M. local time. By the end of May, the planet appears above and slightly left of Castor and Pollux, the brightest stars in Gemini the Twins.

The view of Venus through a telescope improves markedly during May. At the beginning of the month, it shows a 17"-diameter disk this is about two-thirds lit. By month's end, the inner planet spans 22" and the Sun illuminates just a touch over half of the disk.

As intriguing as it is to track Venus' changing appearance, the best planets for viewing this month are the two biggest ones. In early May, **Jupiter** lies almost due north as twilight fades away. It remains among the background stars of eastern Cancer all month, edging closer to that constellation's border with Leo. The planet lies to the left of Leo's famous Sickle asterism, which is anchored by the 1st-magnitude star Regulus. At magnitude –2.0, however, Jupiter outshines the star by more than 20 times.

Any telescope delivers breathtaking views of the giant world and its four bright moons, which change position from night to night. Jupiter's disk spans 36" at midmonth and shows a wealth of atmospheric detail. Just be sure to target it in the early evening when it lies higher in the sky and its light passes through less of Earth's image-distorting blanket of air.

As Jupiter dips lower in the west during the evening hours, another fine sight climbs higher in the east: the constellation Scorpius the Scorpion with its planetary intruder **Saturn**. The ringed planet currently moves westward relative to the background stars and slides from Scorpius into Libra during May's second week.

Some 10 days after its border crossing, on May 23, Saturn reaches opposition and peak visibility. At this point in its orbit, it lies opposite the Sun in our sky and thus rises at sunset, appears highest in the north around midnight local time, and sets as the Sun comes up. A planet at opposition also lies closest to Earth, so it shines brightest and appears largest when viewed through a telescope. Saturn peaks at magnitude 0.0 and its ring system, which spans 42.1" and tilts 24° to our line of sight, circles an 18.5"-diameter disk. In moments of steady seeing, the Cassini Division stands out through 10-centimeter and larger telescopes.

Our final planet puts in a brief appearance in early May. **Mercury** reaches greatest elongation May 7, when it lies 21° east of the Sun and appears about 5° high in the northwest a half-hour after sunset. Use binoculars to spot the 0th-magnitude planet against the twilight glow. A telescope reveals Mercury's 8"-diameter disk and crescent phase.

Mars remains hidden in the Sun's glare throughout May. It will be in conjunction with our star in June and will return to view low in morning twilight during August.

The starry sky

May evenings are a great time to get acquainted with the southern heavens. Crux the Cross climbs highest in the sky around 9 P.M. local time, when it appears upright and boldly draws our gaze toward the south. It makes an excellent starting point for exploring the sky's wonders. A good way to begin is to trace out the imaginary circle that marks a declination of –60°, which corresponds to a circle 30° in radius centered on the South Celestial Pole.

The circle essentially bisects the conspicuous constellation Crux. Beta (β) Crucis lies just 0.3° north of the circle and the famous Jewel Box Cluster (NGC 4755) lies a similar distance south. Whenever you're in this vicinity, it's worth looking at the Jewel Box through binoculars or a telescope.

Tracing the circle eastward — to the left in our current evening sky — from Crux, it edges past the two pointer stars: Alpha (α) and Beta Centauri. These gems also lie within 1° of our declination marker. Don't miss the opportunity to view Alpha, perhaps the southern sky's most famous double star, through a telescope.

By now, you probably have a good idea of how the circle will continue. As you shift your gaze into the southeastern sky, the lovely globular cluster NGC 6752 in Pavo lies just 1' from our circle. Glowing at magnitude 5.4, it is one of the sky's brightest globulars and visible to the naked eye under good conditions. It resolves into stars easily through relatively small telescopes.

The circle misses magnitude 1.9 Alpha Pavonis by only a few degrees and magnitude 2.9 Alpha Tucanae by less than 1°. Continuing in an anticlockwise direction, the circle passes 3° south (above) of magnitude 0.5 Achernar, the sky's ninth-brightest star. From there, it's easy to imagine the circle's path up through the southwestern sky, where it passes directly between brilliant Canopus and the Large Magellanic Cloud.

A little higher in the sky and only 0.8° south of the circle is the naked-eye open cluster NGC 2516. It's a wonderful sight through binoculars and one I never miss when I'm in the area.

Skimming within 1° of both Epsilon (ε) and Iota (ι) Carinae, two of the four prominent stars that make up the "False Cross," the circle passes through the center of the Eta Carinae Nebula (NGC 3372). Indeed, Eta (η) Carinae itself, a famous variable that was the sky's second-brightest star for a time in the 19th century, is at a declination of –59.7°. It is in a beautifully rich part of the sky worth exploring through telescopes of any size.

Our circular journey wraps up back at Crux. But by now, assuming you've spent a healthy amount of time gazing at many of the southern sky's most fascinating objects, you should find the Cross has moved noticeably to the west.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
9 P.M. May 1
8 P.M. May 15
7 P.M. May 31

Planets are shown at midmonth

MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

MAY 2015

Calendar of events

4 Full Moon occurs at 3h42m UT

5 The Moon passes 2° north of Saturn, 16h UT

7 Mercury is at greatest eastern elongation (21°), 5h UT

11 Last Quarter Moon occurs at 10h36m UT

12 Mercury passes 8° north of Aldebaran, 1h UT

The Moon passes 3° north of Neptune, 21h UT

15 The Moon is at perigee (366,024 kilometers from Earth), 0h18m UT

The Moon passes 0.2° south of Uranus, 12h UT

17 Asteroid Herculina is at opposition, 22h UT

18 New Moon occurs at 4h13m UT

19 The Moon passes 6° south of Mercury, 7 UT

Mercury is stationary, 11h UT

21 The Moon passes 8° south of Venus, 19h UT

23 Saturn is at opposition, 2h UT

24 The Moon passes 5° south of Jupiter, 7h UT

25 First Quarter Moon occurs at 17h19m UT

26 The Moon is at apogee (404,244 kilometers from Earth), 22h12m UT

30 Mercury is in inferior conjunction, 17h UT

Venus passes 4° south of Pollux, 17h UT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

Unlock the MYSTERIES of the COSMOS!

Each monthly issue of ***Astronomy*** magazine is packed with all the tools you need to get the most from exploring the universe. Whether you're a beginner or an experienced stargazer, ***Astronomy*** can help you enjoy every minute under the stars!

Your subscription will include:

- Stunning images of the universe
- The latest in astronomy and space news
- Monthly columns from the best writers in the field
- Tips for locating stars, planets, and deep-sky objects
- All you need to know about the latest skywatching events

BONUS: Subscribers also get unlimited premium content on **Astronomy.com!**

Subscribe now and SAVE!

Visit www.Astronomy.com

Mon.-Fri., 8:30 a.m.–4:30 p.m. CST. U.S. call 1-800-533-6644

Outside U.S. and Canada, call 262-796-8776, ext. 661

P21323

A53A